An Unforgettable Visit to the FAST Telescope

By Michel Blanc

The Five-hundred-meter Aperture Spherical radio Telescope (FAST) in Dawodang in the southwestern province of Guizhou.
(Photo: National Astronomical Observatories of China, Chinese Academy of Sciences, October 2017)

For several months I heard of the Five-hundred-meter Aperture Spherical radio Telescope (FAST) and dreamed of visiting it. FAST is a myth: the largest radio telescope in the world, a gigantic 500-meter-wide dish, built by Chinese astronomers in a remote countryside of Guizhou Province in southern China, performing its first test operations and listening to the faint murmurs of the distant universe.

And now, with Alain Cirou sitting next to me, we are riding the high speed train from Kunming, the capital of Yunnan province, to Guiyang, the capital of Guizhou Province. Through the window, a fascinating landscape moves at a speed of 300 km/h. This unique succession of eroded hills and deep hollows, entirely painted in green by dense vegetation, is the famous "karst landscape" which is often the iconic representation of China for westerners. There, after hundreds of site visits, scientists had found the ideal landscape form, broad and hollow enough to host a new giant of radio astronomy.

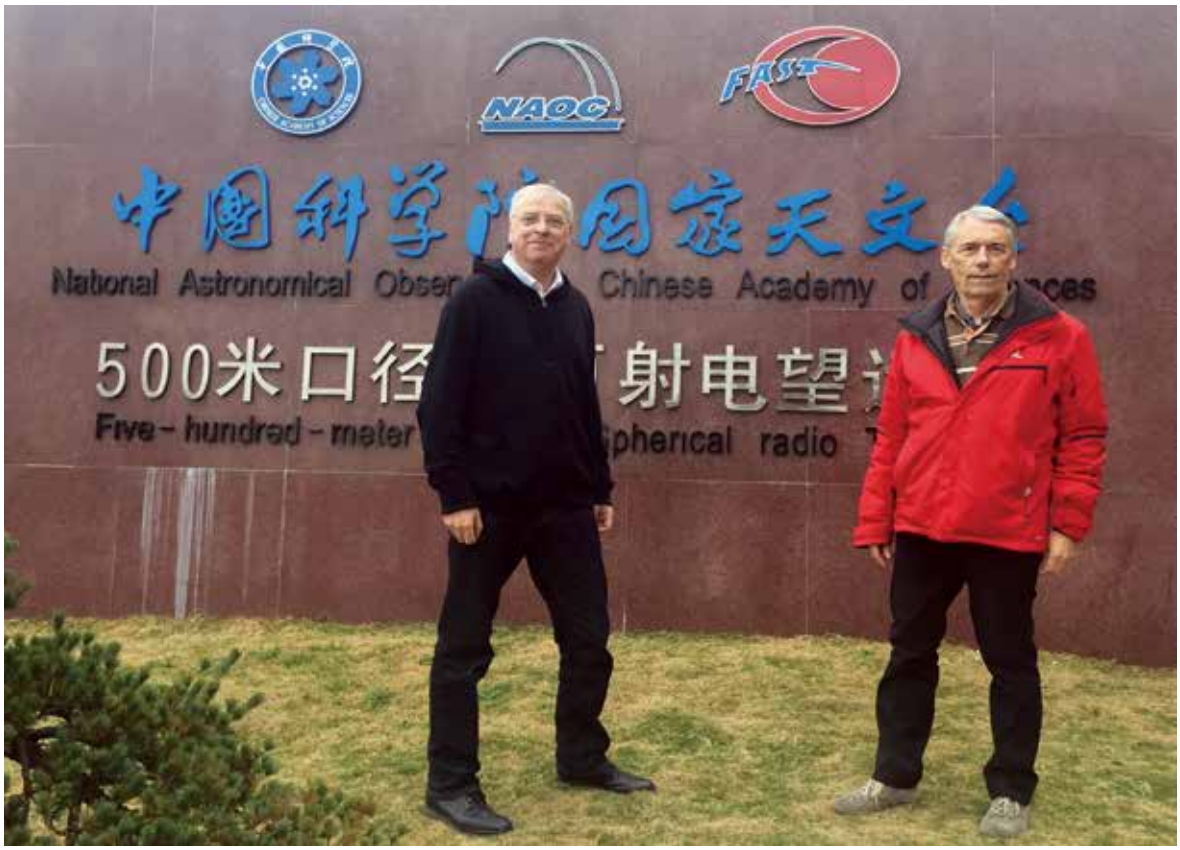
After a bit of wonderful waiting, we are finally going to see FAST! In the car that takes us from Guiyang to FAST, we are holding our breath.

Meeting FAST

We are greeted at the entrance of the brand new FAST operations and life building by Dr. TANG Ningyu, a young, friendly and passionate astronomer.

We want to see FAST immediately, so Ningyu takes us there. On our way to the telescope, Alain and I prepare our eyes for an extreme impression. But it is only after its final curl that FAST unveils its majesty to us. All of a sudden, in just a few steps, we reach the edge of the gigantic dish! It is actually difficult to realize that FAST is "only" 500 meters wide, so strong and breathtaking is the impression produced by discovering in the same view its breadth, its depth, and the elegant form of the focal cabin which seems to be just floating above us!

The three of us follow a narrow trail which, spiralling down along the slopes of the depression, takes us progressively deeper and deeper under the reflector, until we reach its bottom. It is only then, as we walk down under the antenna net, that I realize the extreme technical complexity of this "cosmic ear": 6,670 cables anchoring its structure to the bedrock, and



Michel Blanc (right) and Alain Cirou at the gate of FAST in November 2017. (Photo: Alain Cirou)

Michel Blanc is a French astronomer and planetary scientist. He is currently a researcher at the Institut de Recherche en Astrophysique et Planétologie (IRAP), Toulouse, France, and visiting professor at the State Key Laboratory of Space Weather, National Space Science Center under the Chinese Academy of Sciences in Beijing. He is interdisciplinary scientist of the Cassini-Huygens mission, co-proponent/co-investigator of NASA's Juno mission, and lead proponent of the LAPLACE mission concept, a mission to Europa and the Jupiter system which is under implementation by ESA now as JUICE.

Alain Cirou is the editor of the French magazine *Ciel & Espace*, director general of the French Astronomical Association, and scientific consultant of Europe 1, a French category E private radio station. He is regularly invited in various media as a specialist in astronomy. He is also the author of *Apprendre à observer le ciel* (1988) and *L'infiniment loin* (1992) among other publications. His name was given to Asteroid 11158 by the International Astrononcical Union.

2,225 actuators pulling 4,450 triangle-shaped reflectors to form the telescope's surface. During observation, Ningyu says, the telescope adapts itself to a parabolic shape with an accuracy less than 5 mm.

We discover one of the two keys success recipes of FAST: for each of the directions it listens to, FAST uses its active surface to perfectly focus the faint radio signals received from distant objects into the tiny horn of its suspended focal cabin, where they combine coherently before being detected, amplified and transformed into an electrical signal by an ultra-sensitive, low-noise receiver.

The focal cabin is the other key success recipe of FAST. It continuously performs a slow and undetectable aerial ballet controlled by six giant rods, which maintain it at a height of 138 meters above the bottom of the reflector and control its horizontal position with a centimeter accuracy. Thanks to this horizontal motion of its focus, FAST can explore the cosmos not just along its vertical, but also in all directions up to 20 degrees away from zenith. This angular agility, combined with the rotation of our planet, approaches the performance of a steerable telescope and allows astronomers to explore an extremely broad sky!

Looking at this distant focal cabin through the giant wired reflecting surface, we realize that FAST is even more impressive when seen from below than from above.

Great Telescope for Great Science

We walk back up the slopes of FAST and to the control room, where Ningyu shows us a video which tells the story of the construction of FAST, the gigantic work and its incredible result. In this video, we discover "in person" for the first time Prof. NAN Rendong, the "spiritual father" of FAST. NAN describes how the Chinese astronomy community, after having offered without success to host the International Square Kilometer Array (SKA) project in southern China, proposed to build the world's largest radio telescope on one of the planned sites, using its own resources and capitalizing on a unique diversity of technical skills and scientific disciplines: astronomy, radio science, mechanics, coherent and adaptive optics, optimal control, geology, hydrology, etc. Together, they managed to turn the inhospitable landscape of a giant karstic depression into a habitat perfectly adapted to the deployment of this giant cosmic ear. NAN's voice is broken from illness but so moving!

We cannot keep from asking ourselves what secrets of our universe this giant cosmic ear is going to unravel. Our following visit to the control room, where a large team of astronomers and engineers operates the giant machine during the current test period, gives us preliminary answers, exciting enough for us to realize that FAST is a fantastic discovery machine ready to explore, among other things, three fundamental issues about the universe.

First, with unprecedented sensitivity, FAST will be able to map for the first time the distribution of atomic hydrogen formed at the very beginning of our universe, and help us understand how the first stars and galaxies were born.

Second, FAST is expect to discover several thousand new pulsars—collapsed remnants of stars rotating at an extremely high but regular speed—and contribute to the

detection of gravitational waves produced by the merger of super-massive black holes from far away.

Finally, FAST might play an instrumental role in the search for extraterrestrial life. It plans to contribute a small fraction of its time to systematically listen to the nearby planets of our Galaxy, and try to detect artificial radio signals emitted by advanced technology. Our limited understanding of the emergence of life on our planet has taught us that life, when it occurs, takes billions of years to evolve into intelligent beings and perhaps, with an unknown probability occurrence, to the emergence of technology-driven civilizations. This is probably a very short time compared to the age of the universe. With its sensitivity, FAST has a chance in unravelling this huge mystery for mankind on Earth.

These are just some of the discoveries FAST is going to make, we believe. Many more are on the way, unpredictable but with a full harvest of surprises for sure, partly answering the old questions and partly opening new avenues of research.

In the control room, we watch the NAOC team on duty to monitor a pulsar timing observation. Of the 20 or so astronomers, engineers and technicians present, the oldest one is just 30, including a young and talented female engineer named YAO Rui who is in charge of the focal cabin. After NAN and his team of "builders", a generation of "explorers" has taken command of the cosmic ear— a generation which, we can feel, has all the necessary skills, motivations and indefectible faith in its success to hold the wonderful promises of the FAST telescope. It is these young men and women who are going to ripe the scientific fruits of the gigantic design and construction led by NAN Rendong and his colleagues at NAOC in the past decades.

As we slowly walk out of the world of FAST, we know that the largest radio telescope of the world is in very good hands. NAN's dream has materialized into a unique exploration machine, ready for an exceptional harvest of scientific discoveries!

Acknowledgements

I would like to dedicate this article to the memory of Prof. NAN Rendong, the late chief scientist and chief engineer of FAST, the one who dreamed this beautiful project and devoted the last part of his life to make it happen. I would also like to express my deep gratitude to the directors and staff of the National Astronomical Observatories, Chinese Academy of Sciences (NAOC): Prof. XUE Suijian, deputy director of NAOC; Prof. LI Di, current chief scientist of FAST; Mr. ZHANG Shuxi, head of the FAST project office; Dr. TANG Ningyu, our wonderful host; Drs. RUI Yao and JIANG Peng, for their kindness in answering my questions; Prof. CHEN Xuelei, for his enlightening explanations of the cosmology objectives of FAST.

Young scientists are working in the control room of FAST. (Photo: Alain Cirou)