

CHINA'S BIG SCIENCE FACILITIES

THE SKY EYE

**FIVE-HUNDRED-
METER APERTURE
SPHERICAL RADIO
TELESCOPE (FAST)**

Rendong Nan *Editor*

 浙江教育出版社
ZHEJIANG EDUCATION PUBLISHING HOUSE

 Springer

China's Big Science Facilities

“Big science” facilities are major elements of science and technology infrastructure, and important symbols of China’s scientific and technological development. This popular science book series presents the background, history and achievements of the Chinese Academy of Sciences in terms of constructing and operating big scientific facilities over the past few decades.

The series highlights the major scientific facilities constructed in China for pioneering research in science and technology, and uses straightforward language to describe the facilities, e.g. the fully superconducting Tokamak fusion test device (EAST), the National Protein Science Research Facility, Lanzhou Heavy Ion Accelerator, Five-hundred-meter Aperture Spherical Telescope (FAST), etc. It addresses the respective facilities’ research fields, scientific backgrounds, technological achievements, and strategic and fundamental contributions to science, while also discussing how they will improve the development of the national economy. Supplementing the main text with a wealth of images and linked videos, the book offers extensive information for members of the general public who are interested in scientific facilities and related technologies.

More information about this series at <http://www.springer.com/series/16530>

Rendong Nan
Editor

The Sky Eye

Five-Hundred-Meter Aperture Spherical
Radio Telescope (FAST)

Editor

Rendong Nan
National Astronomical Observatory of China
Chinese Academy of Sciences
Beijing, China

Translated by

Xiaobing Chen
Beijing Foreign Studies University
Beijing, China

Qiuju Huang
Beijing Foreign Studies University
Beijing, China

ISSN 2662-768X

China's Big Science Facilities

ISBN 978-981-16-3823-7

ISSN 2662-7698 (electronic)

ISBN 978-981-16-3824-4 (eBook)

<https://doi.org/10.1007/978-981-16-3824-4>

Jointly published with Zhejiang Education Publishing House

The printed edition is not for sale in China Mainland. Customers from China Mainland please order the print book from Zhejiang Education Publishing House.

Translation from the Chinese Simplified language edition: 观天巨眼——五百米口径球面射电望远镜 (FAST) by Rendong Nan et al., © Zhejiang Education Publishing Group 2018. Published by Zhejiang Education Publishing Group. All Rights Reserved.

© Zhejiang Education Publishing House 2021

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publishers, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publishers nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publishers remain neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.

The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Editorial Board

Editor-in-Chief:

Rendong Nan

Editorial Board Members:

Jun Yan
Xiaonian Zheng
Bo Peng
Shuxin Zhang
Qiming Wang
Di Li
Peng Jiang
Qi Li
Jun Pan
Yi Wang
Shimo Yang

Editors:

Haiyan Zhang
Lei Qian
Caihong Sun
Chengmin Zhang
Wenjing Cai
Aiyang Zhou
Chengjin Jin

Li Xiao
Dongjun Yu
Qing Zhao
Boqin Zhu
Wenbai Zhu
Lichun Zhu
Ming Zhu
Liqiang Song
Mingchang Wu
Baoqing Zhao
Ming Zhu
Gaofeng Pan
Hui Li
Rui Yao
Youling Yue
Bo Zhang
Rurong Chen
Boyang Liu
Li Yang
Na Liu
Jiatong Xie
Yan Zhu
Hongfei Liu
Zhisheng Gao

Series Foreword

As a new round of technological revolution is burgeoning, it will exert a direct impact on survival of a country whether or not it can gain insight on the future technological trends and grasp new opportunities from the revolution. In face of the major opportunities in the twenty-first century, China is intensively formulating the innovation-driven development strategy and building an innovation-based country in this critical era to achieve a moderately prosperous society in an all-round way.

Scientific and technological innovation and popularization remain two wings for innovation-driven development of a nation. In particular, popular science affects the awareness of the general public for science and technology as well as social and economic development. Scientific education is thus highly practical for implementing the innovation-driven strategy. Contemporary science pays more attention to public experience and engagement. The word “public” covers various social groups that exclude those in scientific research institutions and departments. The “public” also includes decision-makers and management personnel in government agencies and enterprises, media workers, entrepreneurs, science and technology adopters, etc. Barriers that impede the innovation-driven strategy will emerge if any group falls behind this new revolution; avoiding and removing the possible barriers will strategically improve the quality of human resources, enhance mass entrepreneurship and innovation and build a moderately prosperous society in an all-round way.

Science workers are primary creators of scientific knowledge who undertake the mission and responsibility for science popularization. As a national strategic power in science and technology, Chinese Academy of Sciences (CAS) has always attached equal importance to this mission in addition to scientific innovation and incorporated the mission into key measures of the “Pioneering Action” Plan. CAS enjoys rich and high-end technological resources, such as the high-caliber experts represented by CAS members, advanced research facilities and achievements represented by the Big Science Project and excellent scientific popularization base represented by the national scientific research and popularization base. With these resources in place, CAS implements the “High-level Scientific Resource Popularization” Plan to transform the resources into popular facilities, products and talents to benefit trillions of the public. Meanwhile, CAS launches the “Science and China” program, a scientific education plan, to mobilize more effectively the “popularized high-end

scientific research resources” for scientific education targeted at the public and the integration of science and education.

Scientific education requires not only dissemination of scientific knowledge, approaches and spirit to enhance overall scientific literacy of the country, but also creation of scientific environment to enable scientific innovation to lead sustainable and sound social development. For this reason, CAS cooperates with Zhejiang Education Publishing House to launch the CAS Scientific and Cultural Project. This is a large-scale scientific and cultural communication project on the basis of CAS research findings and expert teams to improve the scientific and cultural quality of the Chinese citizen in an all-round manner and to serve for the national strategy of rejuvenation by advancing science and technology. On the basis of the target group, the project is categorized to two series, i.e., the Adolescent Scientific Education and the Public Scientific Awareness, respectively, for the adolescent and the general public.

The Adolescent Scientific Education series aims to create a series of publications that draw on latest scientific research findings and introduce the status quo of scientific development in China; to cultivate the adolescent’s interest in science study; to educate them about basic scientific research approaches; and to inspire them to develop rational scientific way of thinking.

The Public Scientific Awareness series aims to educate the general public about basic scientific approaches and the social significance of science and encourage the public to engage in scientific affairs, thus the project will enhance the capacity the public of conscientiously applying science to their life and production activities, improve efficiency and promote social harmony. In the near future, publication series of CAS Scientific and Cultural Project will constantly come out. I hope that these publications will be welcomed by the reader and that through coordination among CAS science workers, science icons such as Qian Xuesen, Hua Luogeng, Chen Jingrun and Jiang Zhuying, will be more familiar to the public. As a result, the truth-pursuing spirit, rational thinking and scientific ethics will be fully promoted, and the spirit of science workers in courageous exploration and innovation stands eternally in the history of human civilization.



December 2015

Chunli Bai
President of Chinese Academy of Sciences;
Secretary of Leading Party Members’ Group
Beijing, China

Preface

A telescope is an instrument which can zoom in distant objects so that people can see clearly. Ordinary optical telescopes are often seen in life and usually consist of objective lens, steering prisms, eyepieces and lens cones. Astronomers use telescopes to observe cosmic space. In 1609, the Italian scientist Galileo Galilei pointed his homemade telescope to the stars for the first time, an unprecedented feat that ushered in a new era of astronomical observation.

Both light and radio signals are electromagnetic waves that propagate at the speed of light, only differing in wavelengths. For thousands of years, man has merely observed the universe through the visible spectrum, while the radiation from celestial bodies covers the entire electromagnetic spectrum. In 1931, Karl Jansky accidentally discovered electromagnetic radiation from the center of the Milky Way. His discovery turned a new page in astronomy, marking the birth of radio astronomy. The emerging discipline contributed to astronomical discoveries in the twentieth century: pulsars, quasars, interstellar and circumstellar molecules and the cosmic microwave background radiation (CMBR), thus becoming the cradle of major discoveries in astronomy. Radio signals from space are extremely weak, so radio telescopes with largest possible apertures are needed to detect more radio signals from celestial objects. However, due to the deformation caused by the weight of telescopes, wind and other factors, the maximum aperture of a conventional trackable telescope can only reach about 100 m.

Twenty-five years ago, a group of Chinese astronomers already envisioned building the “large radio telescope” in China. In 1994, the China Promotion Committee for the Large Radio Telescope was established. Rarely known even by now, the tenacious team brought together over 100 experts from more than 20 universities and institutes across the country to complete the feasibility study of key technologies for large radio telescopes and put forward a preliminary idea for an innovative program to independently build the world’s largest single-aperture spherical telescope in China. After that, progress had been made one after another, including site investigation, key technology breakthroughs, project design, construction and acceptance of scaled-down models. Finally, they presented a clear plan for the “Five-hundred-meter Aperture Spherical Radio Telescope (FAST),” which was approved in 2007.

The FAST project is a major national science and technology infrastructure construction project of “the Eleventh Five-Year Plan.” It intends to build the world’s largest single-aperture radio telescope—the Five-hundred-meter Aperture Spherical Telescope in one of natural karst depressions in Guizhou Province to achieve astronomical observation over a large sky area with high precision. Located in the Dawodang depression, a natural basin in Pingtang County, Guizhou, Southwest China, FAST began construction on March 25, 2016, and was inaugurated on September 25, 2016. Known as the “China Sky Eye,” it is a big science facility with independent intellectual property rights and the world’s largest and the most sensitive single-aperture radio telescope designed, developed and organized by Chinese scientists.

Throughout the five and a half years, thousands of engineering and scientific personnel, workers and managers have been engaged in this intense, orderly and ingenious construction. They overcame a series of difficulties in Dawodang depression, such as bad weather and harsh environment, and designed and implemented one ingenious process after another to make the FAST project a reality step by step. In the process, more than 20 major contractors have completed systematic tasks including site excavation, ring beams, cable nets, panels, actuators and feed support towers, cable drive system, docking platforms, integrated wiring and electromagnetic compatibility.

This book is a popular science book written by the FAST engineering team, which is organized by Mr. Nan Rendong during his lifetime. The team tries to make people understand what FAST is, what it can do, why it was built and how it was completed. FAST is a powerful instrument for human to explore the universe, offering unprecedented opportunities for new scientific discoveries. If the book attracts more people to understand and love astronomy, then its publication will be more significant.

Gratitude is extended to the editors of Zhejiang Education Publishing House for their valuable comments from the book’s planning to finalization, as well as all colleagues who contributed to the planning, writing, finalization and printing of this book. Finally, we would like to dedicate this book to our esteemed Mr. Rendong Nan.

December 2018

Jun Yan (严俊)
Manager of the FAST Project

Contents

Towards the Sea of Stars	1
Haiyan Zhang, Lei Qian, Caihong Sun, Chengmin Zhang, Wenjing Cai, Aiying Zhou, Chengjin Jin, Li Xiao, Dongjun Yu, Qing Zhao, Boqin Zhu, Wenbai Zhu, Lichun Zhu, Ming Zhu, Liqiang Song, Mingchang Wu, Baoqing Zhao, Ming Zhu, Gaofeng Pan, Hui Li, Rui Yao, Youling Yue, Bo Zhang, Rurong Chen, Boyang Liu, Li Yang, Na Liu, Jiatong Xie, Yan Zhu, Hongfei Liu, Zhisheng Gao, and Xiaobing Chen	
The “China Sky Eye” Explores the Universe	17
Haiyan Zhang, Lei Qian, Caihong Sun, Chengmin Zhang, Wenjing Cai, Aiying Zhou, Chengjin Jin, Li Xiao, Dongjun Yu, Qing Zhao, Boqin Zhu, Wenbai Zhu, Lichun Zhu, Ming Zhu, Liqiang Song, Mingchang Wu, Baoqing Zhao, Ming Zhu, Gaofeng Pan, Hui Li, Rui Yao, Youling Yue, Bo Zhang, Rurong Chen, Boyang Liu, Li Yang, Na Liu, Jiatong Xie, Yan Zhu, Hongfei Liu, Zhis heng Gao, and Xiaobing Chen	
Pillars of a Great Power—Intelligent Manufacturing in China	57
Haiyan Zhang, Lei Qian, Caihong Sun, Chengmin Zhang, Wenjing Cai, Aiying Zhou, Chengjin Jin, Li Xiao, Dongjun Yu, Qing Zhao, Boqin Zhu, Wenbai Zhu, Lichun Zhu, Ming Zhu, Liqiang Song, Mingchang Wu, Baoqing Zhao, Ming Zhu, Gaofeng Pan, Hui Li, Rui Yao, Youling Yue, Bo Zhang, Rurong Chen, Boyang Liu, Li Yang, Na Liu, Jiatong Xie, Yan Zhu, Hongfei Liu, Zhisheng Gao, and Xiaobing Chen	

Long March of Dream Pursuers	133
Haiyan Zhang, Lei Qian, Caihong Sun, Chengmin Zhang, Wenjing Cai, Aiying Zhou, Chengjin Jin, Li Xiao, Dongjun Yu, Qing Zhao, Boqin Zhu, Wenbai Zhu, Lichun Zhu, Ming Zhu, Liqiang Song, Mingchang Wu, Baoqing Zhao, Ming Zhu, Gaofeng Pan, Hui Li, Rui Yao, Youling Yue, Bo Zhang, Rurong Chen, Boyang Liu, Li Yang, Na Liu, Jiatong Xie, Yan Zhu, Hongfei Liu, Zhisheng Gao, and Xiaobing Chen	
Major Events in FAST History	139

Towards the Sea of Stars



Haiyan Zhang, Lei Qian, Caihong Sun, Chengmin Zhang, Wenjing Cai, Aiying Zhou, Chengjin Jin, Li Xiao, Dongjun Yu, Qing Zhao, Boqin Zhu, Wenbai Zhu, Lichun Zhu, Ming Zhu, Liqiang Song, Mingchang Wu, Baoqing Zhao, Ming Zhu, Gaofeng Pan, Hui Li, Rui Yao, Youling Yue, Bo Zhang, Rurong Chen, Boyang Liu, Li Yang, Na Liu, Jiatong Xie, Yan Zhu, Hongfei Liu, Zhisheng Gao, and Xiaobing Chen

While looking up to the sky, humans always wondering who we are, where we come from and whether we are alone. In the vast universe, are there other civilizations? For thousands of years, man has merely observed the universe through the visible spectrum, while the radiation from celestial bodies covers the entire electromagnetic spectrum. As radio astronomy observes radio signals from the space, radio telescopes with largest possible apertures are needed to detect more radio signals from celestial objects. Under the mysterious and deep starry sky, FAST serves as a “Sky Eye”, leading us to explore wonders and secrets of the universe.



The Shanghai 65 m Radio Telescope (“Tianma”), built in 2012, is the largest fully steerable telescope in Asia