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Preface: Planning the scientific applications of the Five-hundred-meter Aperture Spherical radio Telescope

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Abstract The Five-hundred-meter Aperture Spherical radio Telescope (FAST) is by far the largest telescope of any kind ever built. FAST produced its first light in September 2016 and it is now under commissioning, with normal operation to commence in late 2019. During testing and early science operation, FAST has started making astronomical discoveries, particularly pulsars of various kinds, including millisecond pulsars, binaries, gamma-ray pulsars, etc. The papers in this mini-volume propose ambitious observational projects to advance our knowledge of astronomy, astrophysics and fundamental physics in many ways. Although it may take FAST many years to achieve all the goals explained in these papers, taken together they define a powerful strategic vision for the next decade.

Key words: radio telescopes: FAST

In the last few years, scientific observations have begun on several powerful new radio telescopes. In many ways, the Five-hundred-meter Aperture Spherical radio Telescope (FAST) is the most impressive of all these new instruments, a list that includes MeerKAT (Camilo et al. 2018), ASKAP (Johnston et al. 2007), MWA (Tingay et al. 2013), LOFAR (van Haarlem et al. 2013), APERTIF (Oosterloo et al. 2009) and the JVLA (Perley et al. 2011). All of these new instruments represent major investments in scientific infrastructure that also drive improvements in industrial and information technologies. As these telescopes are completed and commissioned, opportunities for new kinds of astronomical observations similarly open new doors and windows leading to new landscapes.

Astronomers have not been waiting idly for FAST and the other new telescopes to be completed. Planning new observations to find new targets and new kinds of objects beyond the reach of existing facilities is one of the most exciting jobs of a professional astronomer. Opportunities to attempt unprecedented projects and observations, that go beyond anything that has been done before, come only once in the careers of most astronomers. The papers in this mini-volume of Research in Astronomy and Astrophysics are reports of planning exercises by international teams of radio astronomers focused on how best to apply the unprecedented power of the FAST radio telescope. Now that commissioning is complete and the telescope has begun its first major survey, these papers discussing the possibilities of the new instrument have immediate importance.

Table 1 FAST Technical Specifications

Parameter	Value
Aperture diameter	500 m
Radius of curvature	300 m
Illumination diameter	300 m
Focal ratio f/D	0.461
Latitude	+25° 39′ 11″
Longitude	106° 51′ 24″ E
Zenith angle range	26.4° (with full gain), 40° (with reduced gain)
Frequency coverage	70 MHz–3 GHz
Maximum slew time	10 min
Multi-beam receiver beams	19
Multi-beam receiver frequency range	1.04–1.45 GHz
Multi-beam receiver sensitivity ($T_{\rm rec}$)	20 K
Multi-beam receiver beam width	2.9′

The FAST telescope's specifications and current status are summarized in Table 1, with more details to be found in Li et al. (2018). The first major sky survey, the Commensal Radio Astronomy FAST Survey, CRAFTS, is being planned and its mode tested, using the FAST L-band Array of Nineteen-beams (FLAN) receiver. CRAFTS aims to utilize 100% of FAST's gain in drift-scan mode, which minimizes the complexity and overhead in pointing and tracking with more than 4000 primary panels and the focal-cabin driven by six cables. The key innovation of CRAFTS is its capability of simultaneously recording pulsar, HI galaxy, HI image, and fast radio burst (FRB) (transients) data streams. The related technologies and calibration modes are being demonstrated now and will be published soon. Deeper surveys are also being planned, in particular, those of the Galactic plane and M31 systems. These plans, along with more receivers and other improvements, are pending.

Discoveries such as new pulsars and unknown structure in the interstellar gas of the Milky Way have already been made, with more coming day by day. The capabilities of the instrument are living up to the expectations of the authors of the papers in this mini-volume. Most of the objectives described here will be achieved in the coming decade, many in the next two or three years.

The papers in this mini-volume cover a broad range of science topics, starting with

- the fundamental constants of nature (Chen et al. 2019);
- cosmic rays (James et al. 2019);
- exoplanets (Zarka et al. 2019);
- gravitational radiation (Hobbs et al. 2019);
- pulsar magnetospheres (Wang et al. 2019);
- thermodynamic phases of the interstellar medium (Heiles et al. 2019);
- interstellar masers (Zhang et al. 2019).

The authors are very ambitious. Given the excellent progress of FAST commissioning and its expected transition into normal operation in 2019, such optimism is justified. Related to and also beyond the scope of this mini-volume, there has been growing interest in the science potential of FAST. Yu et al. (2017) predicted more than 10 000 HI absorption systems can be discovered by FAST, thus adding a rare, valuable probe of cold baryons. In addition to this mini-volume, an ensemble of recent publications also shed insights into the potential of FAST in various frontiers of radio astronomy. Zhang et al. (2018) looked into FAST's potential of detecting the radio afterglow of gamma-ray bursts. Zhang (2018) emphasized FAST's unique capability of catching remote FRBs to probe the inter-galactic medium. Liu et al. (2018) simulated pulsar detection by FAST and estimated more than 1500 new detections with more than 200 new millisecond pulsars. These are just some examples, many of which are also published in RAA. If all these proposed observations are successful, the effects will advance, even revolutionize, many areas of physics and astrophysics.

More discoveries will be made by the FAST telescope, beyond the expectations described in these papers. When such a powerful new telescope begins its scientific observations, unexpected signals and effects often emerge. However, unexpected discoveries can only be made when scientists are trying to do difficult projects that push the new instrument to its limits of sensitivity and versatility. The authors of the papers in this volume have plans for difficult and demanding observations, going beyond what has been done by other telescopes in the past. Doing these observations may lead to serendipitous discoveries, because of their ambitious and challenging performance requirements. As these projects are begun over the next few years, FAST will have an impact on many areas of astronomy and astrophysics around the world. We cannot know everything it will discover, but these papers describe how FAST may profoundly change our understanding of the universe.

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