Vintage telescope rebooted in the hunt for FRBs

A cost-efficient overhaul of the 50-year-old Molonglo radio telescope will equip it as a standalone fast radio burst detector and localizer, explain Adam Deller and Chris Flynn.

Every minute or so, somewhere in the Universe, a cosmic radio generator flips on with the power of a billion Suns, only to flip off again a hundred times faster than you can blink. These millisecond-duration fast radio bursts (FRBs) bombard the Earth day in and day out from every direction, but we do not know what could birth such short-lived and violent phenomena. Pinpointing their origin with radio telescope arrays requires capabilities that strain the limits of computational resources, but the venerable Molonglo radio telescope near Canberra, Australia, is a surprisingly good match to the requirements.

Spotting a fleeting FRB signal is a huge challenge, as they are smeared almost beyond recognition by their passage through the intervening interstellar and intergalactic plasma. An FRB-finding system must perform an enormous number of computational trials, searching over a range of arrival times and frequency-dependent delays in order to reconstruct a detectable pulse. Adding the requirement for high angular resolution in order to pin an FRB to its host galaxy causes the brute-force computational challenge to explode: for every square degree of the sky to be searched, millions of megapixel images must be processed every second. In order to reach a field of view spanning many square degrees, computational shortcuts are essential.

The Molonglo Observatory Synthesis Telescope (MOST) is perfectly laid out as an efficient FRB finder and localizer. This 53-year-old facility (Fig. 1) is operated by the University of Sydney and consists of two perpendicularly oriented cylindrical reflectors, each arm of length 1.6 km. With the largest collecting area (36,000 m²) of any telescope in the Southern Hemisphere, it is ideal for detecting faint signals.

In 2016, the east–west arm of this ‘cross’ telescope received an early 50th birthday present: new receivers and an FRB-finding digital signal processing system¹ and becoming UTMOST. Using a single, long and narrow cylindrical reflector produces highly elongated ‘pixels’, slashing the total number of pixels (and hence computation in FRB searches) by a factor of 1,000. For almost five years, the joint Swinburne University/University of Sydney UTMOST team has searched 8 deg² of sky near-continuously for FRBs, finding over a dozen^{2,3}. However, by trading away the

Fig. 1 | Part of the north–south arm of the Molonglo cross telescope, pre-upgrade. Credit: Marcus Lower

usage of the second arm of the cross for computational feasibility, the opportunity to identify the source of the fascinating FRBs that it finds is foregone.

To unlock the full potential of this vintage telescope, the UTMOST-2D project is now underway. By deploying new feeds and receivers on the long-dormant north–south arm of the cross (last used in the 1970s!), the Molonglo telescope will once again be able to snap usable instantaneous images of the radio sky. Operating at 850 MHz, its 45-arcsecond angular resolution will suffice in most cases to identify an FRB’s host galaxy from a single burst. To avoid a 1,000-fold increase in computational complexity, the two-dimensional images are not formed and searched continuously — only when the efficient 1D search uncovers an FRB are a precious few milliseconds saved and transformed into a 2D image. As the number of telescope segments (termed modules) on the north–south arm is initially small, this large efficiency gain sacrifices very little sensitivity.

Presently, four modules comprising a few percent of the north–south arm collecting area have been deployed and are being commissioned, with a further eight modules to be deployed soon thereafter. The new modules have three times the field of view of the east–west arm system, with the intersecting region used to localize FRBs. The UTMOST-2D localization system will come online during 2020.

Despite using cost-saving commodity components borrowed from fields such as mobile telephony, the UTMOST-2D system has outstanding performance — calibrator observations show that each new module is ten times more sensitive than an east–west arm equivalent. With a continued deployment of new modules beyond 10% of the arm, the role of the arms could flip, with the more sensitive north–south arm functioning as primary FRB detector. A fully populated north–south arm would resemble the Canadian Hydrogen Intensity Mapping Experiment (CHIME) telescope but with sharper angular resolution; it would be capable of detecting an FRB and monitoring 1,000 radio pulsars per day. As a bonus, the total absence of moving parts in the north–south arm would greatly reduce maintenance costs. □

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