Radio Astronomy: Capabilities and Opportunities

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Capabilities

The major current radio astronomy facilities in Australia are ASKAP, ATCA and Parkes, which are run by CSIRO, and MWA, UTMOST and the UTAS facilities, which are run by University-led consortia. Other domestic facilities that are available at a reduced level include a VLBI/AuScope network and the Mopra and Tidbinbilla facilities. Underpinning these facilities is an extraordinary national instrumentation, engineering and 'backend' capability developed over many years, and recently strengthened by deep involvement by a number of groups in the SKA and its precursors.

Major radio astronomy facilities have traditionally been subject to open-skies policies, which have allowed Australians to reap the benefits of important overseas facilities such as the VLA, ALMA and Arecibo. However, internationally, the trend is away from open skies - for example, the ALMA consortium has set a cap of 5% on non-member time, and non-members cannot submit large proposals.

Historically, the radio astronomy community in Australia is very strong and internationally respected. In 2014, about half the astronomy community listed radio astronomy as one of the techniques that they used, with about a quarter identifying radio astronomy as their primary technique. This is much higher than other countries such as the US where the radio community is around 5%. Our PhD graduates and postdocs have typically gone on to take leadership positions around the world at various radio observatories. With the powerful new SKA pathfinders, membership of the SKA project, and co-hosting of the SKA telescope, radio astronomy is likely to continue to be a significant part of Australia's astronomy future.

Opportunities

As already foreseen in the Decadal Plan, the major new opportunities that present for the remainder of the 2016-2025 decade revolve around ASKAP, MWA and the SKA. Parkes and ATCA are being reinvigorated with new instrumentation but maintaining stable funding until their capabilities are replaced by SKA/MeerKAT will be challenging. ASKAP has performed well over the last few years, with a number of high-profile publications appearing. But the main surveys with full ASKAP are not expected to be fully operational until 2020, so will be massively productive for the remaining period (with caveats noted below). Similarly, MWA upgrades will be useful in improving EOR limits, exploring the low-surface-brightness continuum sky, and further developing analysis and calibration methods (subject to similar caveats). However, the transition to SKA science is no longer likely to start happening at the end of the 2016-2025 decade as envisaged in the Decadal Plan. This gives increased opportunity to better exploit the pathfinders, and better position the community for SKA science leadership. There also remains room for better exploitation of the incredibly radio-quiet MRO site. The tentative 'cosmic dawn' detection by EDGES is a prime example of what is possible.

A major caveat in achieving the community's science goals is the quality of our analysis pipelines, and the ability of our HPC centres to cope with the large data flows from full ASKAP and MWA, and even planned backend upgrades to Parkes and ATCA. Currently, ASKAP and MWA science is limited by access to advanced computing. The Pawsey upgrade is funded but will not be complete until later in 2020. Further attention to HPC and storage needs will be required as data rates increase.

However, the concept of an SKA Regional Centre in Australia (with international connections to SKA partner countries including China), together with the government's interest in 'Big Data', creates an opportunity to develop a Centre which will increase our capacity to upskill the community in HPC techniques and to better process our radio astronomy data.

New opportunities have also emerged in the following areas:

- Fast Radio Bursts (FRBs): large numbers of these events have now been detected and, with ASKAP (and to a lesser extent UTMOST and MWA), there is much opportunity to localize hundreds of events at the arcsec level. This will lead to a better characterization of the intergalactic medium (IGM) and better constraints on the effect of galaxy feedback on IGM parameters.
- The first direct detection of gravitational waves was finally made in 2015 (announced in 2016). This represents a massive leap in opportunity to study the end phase of the evolution of stars and intermediate-mass black holes. The detection in 2017 of a pair of colliding neutron stars represented an even bigger opportunity for electromagnetic (including radio) follow-up, and led to the first localization of a gravitational wave source. Studies of similar events in future is important in understanding the frequency of mergers and the deposition of heavy elements into the interstellar medium. As for the SKA pathfinders, the development of a gravitational wave Data Centre will be beneficial for the storage and processing of pulsar timing data.

Internationally, Australian radio astronomers are well connected with ALMA science, and have good opportunities to collaborate with FAST and Apertif/WSRT science teams, and are leading a major MeerKAT pulsar programme. Less so with MeerKAT continuum/HI science, LOFAR, uGMRT and LMT, which are each extremely capable instruments.

Beyond the Decade

The transition to SKA is upper in the minds of most radio astronomy community members. The capability of even SKA phase 1 will be superb in comparison with the world's current low/mid-frequency instruments, though it will take many years to better the key ASKAP science surveys. SKA-low (in Australia) and SKA-mid (in RSA) will serve the community well, and permit reinvestment of funds that are currently allocated to existing facilities. ASKAP, MWA, and SKA will lead to increased demand for VLBI, which at present in the southern hemisphere is anchored by Parkes and the ATCA. The decadal plan foresaw new funding models or closure for Parkes and the ATCA. The Parkes Telescope has transitioned to a remote operations model and is now essentially self-supporting financially, while still providing 50% access on merit. However, it will be a challenge to maintain these streams in the long term.

Scientific investment in a number of key areas (including EOR science, HI galaxy science, continuum and polarization studies, pulsars/FRB science) will put Australian astronomers in potential leadership positions for SKA science. As above, using the SKA pathfinders as early leverage into the development of SKA Data Centres may give the community an 'SKA-ready' edge over the other member countries.

Finally, there are potential opportunities to better access ALMA time (particularly for large projects) via full ESO membership, and a potential opportunity to partner with NRAO to develop the ngVLA, a large multi-resolution facility intended to operate in the frequency range between the SKA and ALMA.