THE SQUARE KILOMETRE ARRAY RADIO TELESCOPE: AUSTRALIAN DIRECTIONS

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ABSTRACT

The square-kilometre array (SKA) is a major next-generation radio-telescope expected to be completed in the decade 2010 - 2020. As the name implies, it has an effective collecting area of a square-kilometre, or 1 million square metres: the equivalent of more than one hundred, 100 m diameter, dish antennas. This is two orders of magnitude as great as the biggest operational telescopes, giving astronomers the factor of 100 in sensitivity they require to do critical new observations. This paper describes recent Australian SKA research and outlines projects to be undertaken during the next five years.

BACKGROUND

The SKA is being planned and promoted by an international consortium (currently representing 11 countries); Australia is a major player in this group. With interest in the $A1 billion instrument growing, formal international and national project management plans have recently been put in place. A number of deadlines have already been set, with the period 2005-2007 being the target for deciding between competing technological realizations and short-listed candidate sites. Australia has a good chance of hosting the instrument, giving substantial economic and other benefits. Building on an initial CSIRO seed research program, the Australian SKA community has been successful in obtaining funding under the Commonwealth Government's Major National Research Facility (MNRF) scheme.

For an overview of the SKA and a review of the main technology requirements and possibilities, see the invited paper presented at WARS 2000 [1]. Since the time of that review, a number of project developments have occurred. On the international front these include:

- Formation of an International SKA Steering Committee (ISSC) to oversee the project;
- Formation of an Engineering and Management Team, a Science Advisory Committee and a Site Committee to advise the ISSC and to report the deliberations of specialist working groups, and
- Funding, or substantial part-funding, of SKA technology demonstrators in Australia, China, the Netherlands and the USA.

At the Australian level, developments include:

- Formation of an Australian SKA Consortium Committee (ASKACC) with a brief [2] which includes expanding the project nationally and co-ordinating Australian R&D projects;
- Formation of specialist technology and site working groups to advise ASKACC via a national engineering co-ordinator;
- Substantial technical progress in areas such as spherical lens antenna design, radio-frequency interference mitigation, and characterization of remote candidate sites in Western Australia, and
- Announcement in August 2001 of the success of a joint optical-radio astronomy MNRF bid, leading to SKA R&D totalling about $20M over the next five years.

AUSTRALIAN SKA - SOME RECENT HIGHLIGHTS

A few significant outcomes from the last two years are summarized below.

Antennas
With several international partners examining large and small reflector options [3], Australian work has centred on assessing the feasibility of Luneburg Lens antennas [4] and on collaborating with Dutch colleagues working on broad-band (7:1 bandwidth) phased arrays. Fig. 1 shows a small Luneburg Lens under test; current Australian research on new low-loss, light-weight, artificial dielectrics aims to deliver a 4 m diameter prototype lens in mid-2003.

Fig. 1. A 0.9 m diameter Luneburg Lens being tested in CSIRO's near-field test chamber. While small, this Russian lens has allowed refinement of electro-magnetic design and measuring techniques.

RF Interference Mitigation
A "software radio telescope" project, in which signals from the Australia Telescope were recorded and processed coherently, led to a new form of interference mitigation being developed [5]. This "post-correlation" approach produces excellent results in applications where a degree of temporal averaging is permitted; radio astronomy - where signal statistics rather than signals themselves are usually of prime interest - is one such application.

Site Testing
With the support of the Western Australian Government an initial round of site investigations have been completed, the most comprehensive being at Mileura Station, 100 km west of Meekatharra. While more tests are planned at sites around Australia, the RF environment results illustrated in Fig. 2 are impressive - a message well-understood by the international SKA community. The concept of a radio-quiet reserve for any Australian SKA site is also being developed; if successful, it would be a strong additional incentive to build the SKA in this country.

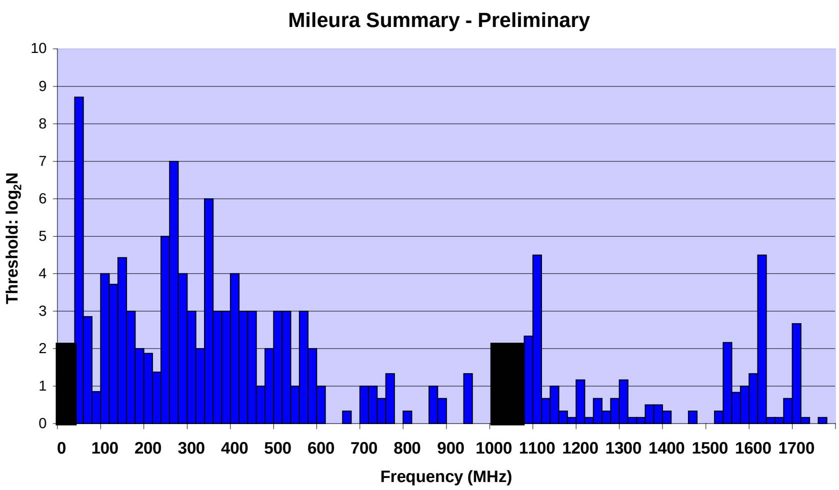

Fig. 2. A preliminary representation of the worst-case signal count (N) present in 20 MHz bands at Mileura Station. Additional temporal statistics show that large blocks of the spectrum are less than 5% occupied. No data are available below 30 MHz and the area near 1000 MHz has not yet been fully analysed.

MAJOR NATIONAL RESEARCH FACILITIES - THE NEXT FIVE YEARS

In May 2001 the Australian astronomical community submitted an MNRF application entitled "Gemini and SKA - Australia's Astronomy Future". The successful outcome, which involves a 50% matching funds arrangement with proponents, will have substantial impacts in both optical and radio astronomy. In the latter case, it will allow Australia to demonstrate a technological capacity which complements its natural and political advantages as a potential SKA host.

The proposal has four main deliverables, spread among various proponents. These are:

- An AT Compact Array multiple antenna demonstrator - a project led by CSIRO involving the use of the ATCA as part of a powerful new technology test-bed;
- A Molonglo large-area demonstrator - led by the University of Sydney and using its 18000 m^2 cylindrical paraboloid telescope as a test-bed for alternative antenna and signal processing technologies;
- A supercomputer simulation facility - led by Swinburne University of Technology with the aim of extending a supercomputer cluster to work in vital SKA astronomy and system design simulations (including imaging simulations), and
- Various enabling technologies - led by CSIRO and focussed on development of key techniques and instruments for the above projects (one major component is a new signal processing engine, or correlator, for the enhanced ATCA).

Apart from the proponents already mentioned, CEA Communications P/L, Advanced Powder Technolgies P/L and the WA Government are also partners in important sub-projects.

SKA demonstrators allow engineers to develop new approaches to array design and, in the case of the Australian instruments, the integration with powerful existing radio telescopes offers exceptionally good astronomical characterization of new hardware and techniques. While effective SKA demonstration is not completely compatible with a simple telescope upgrade, there is sufficient overlap to guarantee astronomers substantial astronomical returns from the new technology, either in familiar areas (sensitivity, angular resolution, etc) or in interesting new ones (such as high time resolution aperture synthesis or multi-beaming interferometry). Information on the proposed Molonglo test bed has been summarized in [6], while the section below shows an idea for the AT Compact Array upgrade. In both cases, important contributions should flow from assessments such as the:

- Performance of multi-beaming antennas;
- Feasibility and performance of photonic signal distribution schemes;
- Performance of signal encoding and processing systems;
- Scientific potential of the concepts adopted;
- Calibration strengths and weaknesses;
- Practicality of new array software concepts and
- Economic feasibility of the technologies under test.

THE ATCA NEW TECHNOLOGY DEMONSTRATOR

This instrument, with an estimated cost of $10M, will combine multi-beaming antenna technologies, dense optical signal transport media, and wideband signal processors incorporating RF interference mitigation features. A possible arrangement is shown in Fig. 3; two SKA mini-stations, based on either Luneburg Lenses or phased arrays, are the most recognizable features.

While demonstration of new SKA technology and techniques is the main driver, adding two stations certainly improves the "classical" telescope performance: for example, the collecting area (and sensitivity) and number of baselines (related to the imaging fidelity) increases by 15% and 86% respectively. Of course, the new correlator is a powerful tool for all astronomy programs, especially those associated with the nearly-complete millimetre-wave upgrade [7].

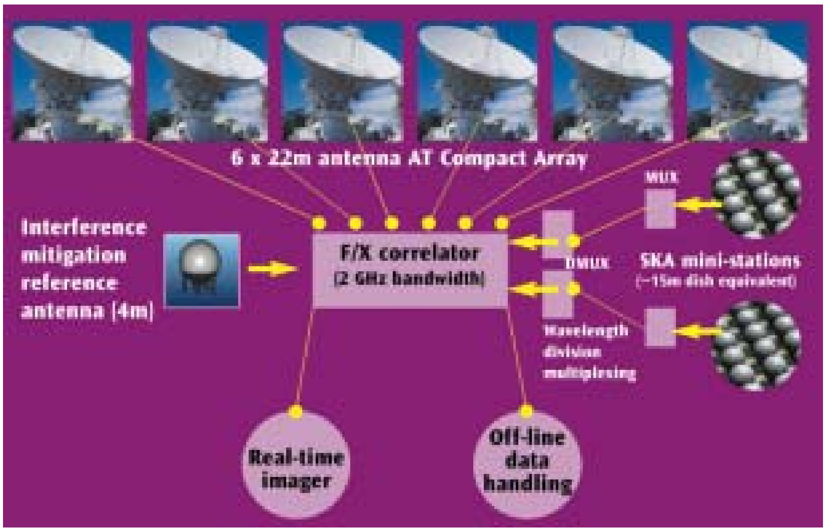

Fig. 3. SKA demonstrator based on the ATCA. The interference mitigation reference antenna is in fact a prototype 4 m Luneburg Lens; the new stations may be based on either lenses or phased arrays, depending on the outcome of initial experimental studies.

CONCLUSION

Australia's contribution to the international SKA project has been strong from the outset. Despite relatively modest funding for Australian demonstrators, there is now a capacity to address key radio science challenges, including efficient multi-beaming antennas and robust interference mitigation techniques. Many results have application outside astronomy and, with the operation of the Australian SKA Consortium, there is an opportunity for interested research partners (including industry partners) to collaborate. The Australian demonstrators are important components of a suite of hardware to be evaluated by the international SKA community in the period 2005-2007. Our instruments are vehicles for testing ideas in SKA system design and will ensure a credible presence in the wider project, regardless of which concept and site are eventually selected.

REFERENCES

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