Overview of the CSIRO/University of Sydney SKA Molonglo Prototype (SKAMP) program

Anne Green, University of Sydney, 9 March 2004

The SKAMP project is largely funded through the MNRF program as a joint venture between the University of Sydney and CSIRO, but also receives some funding through the Australian Research Council (ARC) and other sources. It has two main aims:

1. To demonstrate SKA-relevant technologies, particularly relating to ultra-wideband line feeds for cylindrical geometry antennas, wide-field-of-view imaging and high–speed digital signal processing.

2. To provide a new low–frequency spectral–line facility in the southern hemisphere, building on the existing Molonglo Observatory Synthesis Telescope (MOST) which is owned and operated by the University of Sydney.

As a technology testbed, SKAMP is closely linked to both the Cylindrical Reflector SKA concept proposed by Bunton et al. (2003 SKA White Paper) and the HYFAR ultra-wide-field survey telescope (50-100 square degree FoV at frequencies below 1.4 GHz) proposed by Ekers et al. last year.

As a major national research facility, SKAMP will provide a telescope with large collecting area working in both spectral-line and continuum over a frequency range (300–1000 MHz) not currently covered by any southern-hemisphere telescope.

What will be built?

The outcome from the SKAMP project will be a 2048-channel spectrometer, operating continuously over the frequency range 300–1400 MHz, with an instantaneous operating bandwidth of ∼50 MHz. The angular resolution of the telescope will range from 26 to 126 arcsec with a sensitivity of between 0.02 and 1 mJy/beam and a field-of-view of several square degrees. The technologies to be demonstrated are:

- A wideband feed operating over the whole frequency range (this is the biggest technical challenge)
- RF and IF beam-forming to give extremely wide fields of view
- Digital filterbanks operating at speeds above 100 M samples/sec
- The correlation of a large number of antenna stations

To achieve these outcomes, the project has been divided into three stages.

Stage I (2004): A 96-station *continuum* correlator, with 3 MHz of bandwidth centred at 843 MHz, providing high dynamic-range imaging with correlation processing. This stage uses the existing front-end feeds and signal pathway of the MOST, and can proceed in parallel with the current (2004–6) ARC–funded science programs, SUMSS and the Galactic Plane Survey.

Stage II (2005–6): A 30 MHz–bandwidth *spectral–line* correlator, centred at 843 MHz. This stage will use the existing ring antennas with a new IF/LO distribution and full fibre feeds to each of 88 independent bays of the telescope. The entire 1.6 km of the cylindrical reflector will be fitted, although only 1 LNA per bay will be used, reducing the effective collecting area for this stage.

Stage III (2005–7): 300–1400 MHz *continuous spectral–line capability* with ∼50 MHz instantaneous bandwidth (limited by signal-processing resources). A new contiguous–broadband line feed will be developed and installed on a section of the array as the key new technology. The fraction of the 1.6 km Molonglo telescope which is equipped with the new line feed, and hence the effective collecting area of the telescope for spectral-line studies of redshifted HI, will depend on available funding.

Who is involved?
Current members of the SKAMP team are:

Anne Green	Project leader (University of Sydney, Director Molonglo)
Michael Kesteven	Senior Project Coordinator (ATNF)
Duncan Campbell-Wilson	Site Project Manager at Molonglo (University of Sydney)
Andrew Parfitt	Wideband–Feed Project co-leader (CSIRO)
Bevan Jones	Wideband–Feed project industry partner (Argus Technologies)
Martin Leung	PhD student on APAI scholarship for Wideband–Feed Project
Sergey Vynogradov	Antenna modelling expert (Research Associate, from 2004)
(RF Engineer)	Molonglo–based, to design RF beamformers and LO/IF system and contribute to installation of front-end (from 2004)
John Bunton	Correlator Designer (CSIRO, ICT)
Tim Adams	Correlator Engineer, filterbank design and telescope control

Current funding for SKAMP
The University of Sydney is a participant in the MNRF Program. As set out in the Relationship Agreement, the University of Sydney will provide $900K in matching funds, and the MNRF Program $760K, over the five years of the program.

Other funding support includes a University of Sydney Sesqui R&D Grant of $25K in 2002, an ARC Linkage Project grant of $234K for 2003–5 with industry partners Argus Technologies and CSIRO, and in-kind support from the software company Altium (Protel software and consultation advice to speed the development of the spectral–line correlator and filterbank). Funding for the development of RFI mitigation strategies and tools is agreed in principle with the Department of Defence as part of a collaboration to manage the proposed siting of the new National Operational Headquarters (HQAST).

SKAMP and SKA timelines
The rising profile of the Cylindrical Reflector SKA design over the past year has led in turn to increasing pressure on the SKAMP program to demonstrate several key technologies which are necessary for building a CR SKA. These are (i) a wideband feed operating over the entire frequency range 300-1400 MHz, (ii) the beam-forming techniques needed to image a very large field of view, (iii) a high-speed digital correlator and filterbanks, and (iv) effective removal of terrestrial radio–frequency interference (RFI).

At present, the MNRF and other funding allocated to SKAMP is sufficient to complete Stage II (i.e. a 30 MHz bandwidth spectral correlator centred at 843 MHz and a collecting area $\sim$10,000 m^2). To demonstrate all the key technologies underlying the CR SKA design before the ISSC deadline requires Stage III to be completed by 2007, and in particular requires the development of the wideband line feed to be fast-tracked. This would require *additional resources* beyond those currently allocated through the MNRF program.

The SKAMP science program
SKAMP stage II will provide a 30 MHz observing bandwidth centred at 843 MHz. The improvement in the continuum performance of the telescope will not be dramatic because the 1.6 km maximum baseline of the telescope sets a confusion limit of $\sim$0.2 mJy at 843 MHz (the current SUMSS images reach to 3–5 mJy). However, SKAMP-II offers a powerful tool for studying the neutral hydrogen content of the universe at redshift z=0.65 to 0.7 via HI absorption–line measurements against background radio galaxies and quasars. Little is currently known about HI at this epoch, since the redshifted Lyα absorption lines are not accessible to ground-based optical telescopes.

SKAMP-III will be able to observe HI in absorption over a very wide redshift range from (z=0.4 to 3 or higher). The current funding should allow at least 10% of the telescope collecting area (i.e. $\sim$1500 m^2) to be equipped with the new wide–band feed. If there is a compelling scientific case for equipping the entire 18,000 m^2 collecting area with either a 250–500 MHz or 500–1000 MHz feed, funding for this could be sought from the ARC or elsewhere.