ATNF ATUC Memorandum

To: ATUC
From: Enno Middelberg
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Subject **Summary of 7 mm workshop on 31 May 2005**

A workshop was held to extend the science case for the upgrade of the Compact Array with receivers in the range 25 GHz to 50 GHz. 15 talks were given by members of ATNF, ANU, UNSW, USYD and Swinburne, covering a wide range of galactic and extragalactic astronomy. The talks indicated that this system will be a considerable benefit to the Compact Array and the Australian astronomy community.

The workshop began with a description of the receiver design and the presentation of recent results from tests of the cooled LNAs. The expected system temperatures match the requirements by NASA, who is a major sponsor of the system to use it as a backup tracking station (10 h / week), and hence promise an excellent sensitivity for astronomical observations.

The astronomical contributions can be loosely divided into four topics.

1. **Star formation and stellar evolution**
   The transition from molecular cloud to high-mass ($M>8\ M_{sun}$) star is poorly understood, in contrast to the formation of lower-mass stars. Radio jets, an indicator for accretion disks in low-mass stars, have barely been observed in high-mass stars, and the question remains open whether massive stars form via the same processes as low-mass stars or via coalescence.
   When high-mass stars have finally formed, they ionize their surroundings, forming HII regions of various degrees of compactness. These regions tend to be small and very dense. CA observations at 7 mm will be able to probe these regions as the optical depths of free-free and dust emission are about the same, and the then almost continuous frequency coverage of the CA will allow one to precisely model SEDs from 1 GHz to 100 GHz.
   In the later stages of stellar lifecycles, SiO masers can be observed at 43 GHz in stellar atmospheres. With the CA, they would be visible almost throughout the Milky Way and could be pinned down with high accuracies, yielding valuable insights about stellar dynamics in our Galaxy. Finally, 7 mm offers the opportunity to study SN1987A in more detail. The CA's resolution at 7 mm will be much better matched to HST and Chandra, it will allow to resolve the interactions of the supernova's expanding shell with the ISM and may help to study diffuse shock acceleration.

2. **Molecular lines and masers**
   In the 7 mm band exists a wealth of molecular lines, many of them yet unexplored, which can be used as tracers of various physical parameters. Prominent lines include SiO, OH, methanol, and ammonia, but especially the range 35 GHz to 50 GHz provides access to many more astrophysically interesting lines.
   Methanol masers have been studied predominantly at lower frequencies, because the 25 GHz to 50 GHz range is not commonly accessible. The higher-frequency transitions, however, can provide density and temperature information, data for statistical analysis and appear to be the most suitable for a blind survey.

3. **VLBI**
   The mechanism by which gas in AGN is fed into the central supermassive black holes is still unconstrained by imaging observations, because the regions are very small and very distant. VLBI at 7 mm is an important contribution in the quest for higher angular resolution, because it still provides very good sensitivity. Spectral index studies of radio jets combining 7 mm ATCA observations with 20 cm LBA observations seem plausible because the resolutions are similar. Also SiO masers in stellar envelopes could be targeted, possibly in collaboration with the Japanese VERA network. VLBI observations with a combined VLBA+CA network would yield some of the highest-resolution images available today.
   As Mopra will also get a 7 mm receiver and Tidbinbilla may get improved 7 mm capabilities in the future, an Australian 7 mm network would be formed, yielding images with a resolution of a few milli-arcseconds.
   After the upgrade, the CA could also participate in the next-generation ICRF, which will use observations at 24 GHz and 43 GHz.

4. **The high-redshift universe**
   The most important single molecule to study is CO at high redshifts. CO traces the pools of gas from which stars formed throughout the universe, and have been found in quasars, ULIRGs, sub-mm galaxies, and radio galaxies. Various selection effects influence the conclusions drawn from the few existing observations, and a more general approach is needed to study CO and star formation at high redshifts. The CA at 7 mm is the ideal instrument to do this: at almost any one redshift above z=1.5, the 7 mm band will be the best choice in detection experiments, and in the same range will provide crucially important information about lower transitions which are needed to model the gas in these galaxies. A blind CO survey in the 7 mm band would be much more efficient than at any other frequency.
   A 7 mm-upgraded CA could be used to study the Sunyaev-Zeldovich effect which provides galaxy cluster masses independent of redshift. In a compact configuration, a typical cluster would be detected in 12 h, and with the new correlator in 1 h.

It was generally felt that the 7 mm system will fill an astrophysically valuable gap hitherto left open by the millimetre upgrade, allowing astronomers to almost freely choose their observing frequency at the CA. Given that only few radio telescopes around the world can observe in the 7 mm band at all, this capability emphazises the CA's unique position.

Technical limitations allow only to observe either the 25 GHz to 40 GHz range or the 30 GHz to 50 GHz range, but not the entire range of 25 GHz to 50 GHz where the atmosphere is sufficiently transparent. A poll among the speakers and the audience at the workshop showed that a majority of more than 90% opted for the higher frequency range.