Astrophysical Radio Transients: Surveys and Techniques

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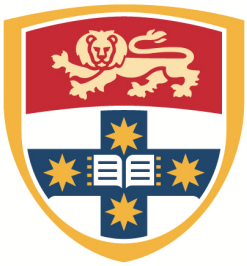

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Pour Michelle, Arianne et Soren.

Abstract

I present two pilot surveys and a range of new algorithms to aid in planning and implementing wide-field radio surveys for transient and variable sources. The first pilot survey is a blind survey for transient and variable radio sources with the Molonglo Observatory Synthesis Telescope at 843 MHz. This survey discovered 53 highly variable sources and 15 transient sources and determined surface densities of $0.268\,\mathrm{deg}^{-2}$ for variable sources and $1.3 \times 10^{-2}\,\mathrm{deg}^{-2}$ for transient sources, with associated timescales of between one day and three years. I also propose two new techniques which were developed for this survey. The first technique provides a post-imaging calibration for image gain. The second technique is a statistical method for verifying whether flux error measurements agree with the scatter in light curves over a population of sources.

I also describe a follow-up survey for prompt radio emission from gamma ray bursts (GRBs) at 1.4 GHz. This survey used a single-dish telescope to automatically slew to a GRB position within 2 min of the gamma ray trigger and performed single-pulse, repeating and low-time resolution searches for variability. This survey discovered single, dispersed pulses following two long GRBs, which are possibly related to the delayed formation of a black hole at the centre of the GRBs. The high-time resolution measurements from this survey are some of the most constraining limits on prompt radio emission from GRBs to date.

I also present two efficient new algorithms for detecting dispersed radio emission in interferometric data: the Chirpolator and the Chimageator. These two techniques excel in the regime of sparse arrays, where they both require substantially lower data rates, and the Chirpolator requires a much lower post-integrator operation rate than the existing algorithms. These techniques are well matched to future supercomputing architectures, where the arithmetic capability is outstripping the bandwidth capability, and are therefore suitable for use by interferometer-based fast transient surveys.

The surveys and techniques described in this thesis will have immediate application to upcoming surveys with the next generation of wide-field radio telescopes, such as the two transients surveys proposed for the Australian Square Kilometre Array Pathfinder.

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3. The SIMBAD database, operated at CDS, Strasbourg, France.
4. SAOImage DS9, developed by the Smithsonian Astrophysical Observatory.
5. The Aladin sky atlas (Bonnarel et al., 2000).
6. Data obtained through the High Energy Astrophysics Science Archive Research Center Online Service, provided by the NASA/Goddard Space Flight Center.
7. Data obtained from the Leicester Database and Archive Service at the Department of Physics and Astronomy, Leicester University, UK.
8. The Q3C spatial indexing extension for Postgresql by Koposov & Bartunov (2006).
9. The Cosmology Calculator (Wright, 2006).
10. The PSRCHIVE software suite (Hotan et al., 2004).

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Statement of Originality

All work performed for this thesis and resulting publications are entirely my own work except as follows.

Chapter 2 : Dick Hunstead supplied the MOST data and provided technical insight into the operations of the MOST, especially the calibration procedures. Barbara Piestrzynski maintained the MOST archive. Duncan Campbell-Wilson supplied some important technical information and maintains the MOST. Elaine Sadler provided useful comments on optical counterparts and Greg Madsen provided help with putting axes on Figure 2.2. The anonymous referee for the resulting paper (Bannister et al., 2011) also provided some extremely useful comments. The co-authors for the paper, Bryan Gaensler, Tara Murphy, Dick Hunstead and Shami Chatterjee, provided general advice on the analysis of the data and comments on the paper drafts.

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Chapter 4 : The original idea of gridding voltages (an idea which is related to, but not exactly incorporated in the Chimageator) was first proposed to me by Tim Cornwell. I discovered the Chimageator imaging optimisations and derived the resulting performance equations. The co-author,

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Publications in this thesis

Chapter 2 along with appendices A and B have been published as Bannister et al. (2011).

Chapter 4 along with appendices C and D have been published as Bannister & Cornwell (2011).

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