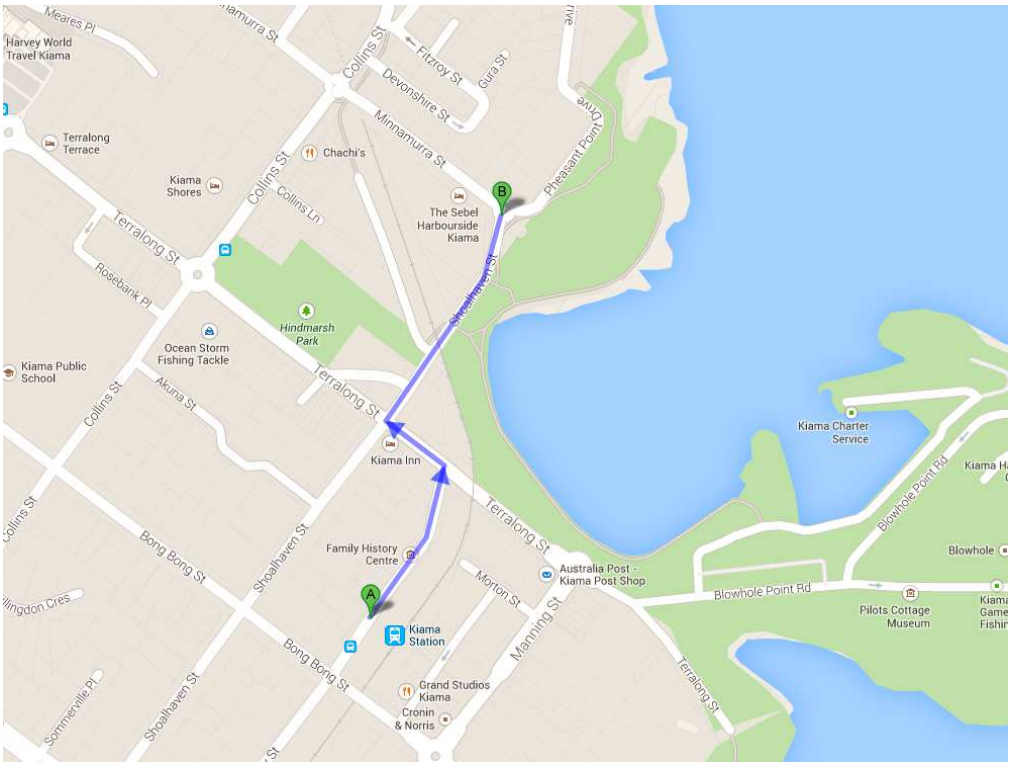
The 8th SKA Calibration and Imaging Workshop (CALIM2014)

Program

Sunday, 2 March

19:00 – 21:00 Ice-breaker welcome reception @ Restaurant 1871

Directions from Kiama station to Sebel Harbourside Hotel (450m walk):



This workshop is sponsored by CSIRO, SKA and ICRAR

Monday, 3 March

8:30 – 9:00 Arrival tea/coffee with freshly baked Danish pastries

9:00 Welcome and logistics

Session I. Status updates

9:10 **Maxim Voronkov**. *ASKAP status and commissioning*

The first stage of the Australian Square Kilometre Array Pathfinder (ASKAP), called the Boolardy Engineering Test Array (BETA), which consists of 6 Mark-I PAF-equipped antennas and digital backends capable of producing 9 beams, has transitioned to become an operational instrument during 2013. In this talk we summarise the current status of the system and describe the commissioning activities resulted in first BETA images

9:35 **Lincoln Greenhill**. *The Large Aperture Experiment to Detect the Dark Ages (LEDA)*

Tracing the IGM's thermal history prior to Reionization is a forefront challenge. In its 1st science season, LEDA targets z$\sim$20, shortly after emergence of the "1st stars", and earlier than that for several other 21 cm arrays. LEDA uses a 512-antenna array part of which is equipped for total-power radiometry. Full correlation processing will enable derivation of antenna calibrations and refinement of foreground models, and interpretation of the radiometry. The LEDA correlator is deployed to the Caltech LWA station. The presentation will describe calibration and imaging requirements.

10:00 Tea/Coffee

Session II. Pipelines

10:45 **Ger van Diepen**. *LOFAR Data Processing Pipeline*

The first version of the LOFAR data processing pipeline has been developed. It is used to do the automatic processing of the MSSS survey observations and the targeted observations. The challenges and the choices made will be discussed as well as future plans to optimize the data processing and add new functionality.

11:10 **Ben Humphreys**. *ASKAP Central Processor: Design and Implementation*

The Central Processor for the Australian SKA Pathfinder (ASKAP) performs calibration, imaging, and science analysis on datasets as large as 100 TB every 8−12 hours. I will provide an overview of the design and implementation, focusing on the hardware platform and software design. I will also discuss design decisions, tradeoffs, and challenges both overcome and remaining.

Monday, 3 March

11:35 **Jack Line**. *RTS Processing and Calibration*

The Real TIme System (RTS) is a calibration and imaging pipeline capable of direction dependent and independent corrections. It employs warped snapshot imaging and peeling to remove foregrounds, using a previously defined surce ctalogue. In this talk I will touch on some approaches to calibration of Murchinson Widefield Array (MWA) data using the RTS, and show some preliminary results comparing differing source models.

12:00 **Laura Richter**. *TBD*

TBD

12:30 Lunch (provided) @ Restaurant 1871

Session III. PAFs and beamforming

14:00 **Andre Young**. *Electronic Sky Derotation for a Phased Array Fed Reflector Antenna*

The beamforming capability of PAF based systems offer the advantage of being able to optimize various figures of merit; this ability is often used to improve the stability of the beam response over the Field-of-View (FoV). One aspect of stabilization is concerned with compensating for parallactic angle rotation in systems that use alt-az mount reflector antennas. Herein an electronic derotation scheme is employed to reposition beams in the FoV as a source field is tracked over a long observation, thereby removing the need for sky rotation compensation in image post-processing. The impact of such a derotation scheme on the gain and noise stability of the system is considered, and the scheme is compared to performing rotation compensation in post-processing.

Monday, 3 March

14:25 **Brian Jeffs**. *PAF Beamformer Calibration Using Distributed Sources*

One of the critical steps in forming well shaped phased array feed (PAF) beampatterns is obtaining array response calibration measurements. This is done by observing a bright and preferably point-like deep space calibrator source while steering the dish in a grid pattern of integration stops which place the calibrator (relative to dish boresight) at every position where a beam mainlobe is to be formed, and every point where a pattern contour constraint is desired. Due to drift in electronic and systematic phase and gain relationships across the array, this time consuming calibration must be periodically repeated at an interval on the order of a few weeks. One of the challenges for smaller aperture dishes such as the ASKAP 12 m instruments is that there may be few suitable continuum calibration sources available with sufficient flux density to yield low error calibrations without unreasonably long integration times. This is particularly true in the Southern Hemisphere. Also, larger aperture instruments being considered for PAF upgrades, such as the GBT and Arecibo telescope, will resolve objects that appear point-like on the smaller dishes. This could adversely affect calibration. In this presentation we will consider addressing these two challenges by using extended objects as PAF beampattern calibrators. It will be shown that for a 12 m dish the Sun and Moon can be used effectively as readily available and very bright calibration sources. A method to exploit more extended sources with a know high surface brightness profiles for PAF calibration on large aperture instruments will also be presented. These two methods will extend the catalog of usable calibration sources for PAF beamforming.

14:50 **Ivan Marti-Vidal**. *Polarization calibration in VLBI with the phased ALMA*

The ALMA Phasing Project (APP) will allow us to use ALMA as one VLBI station. This will be a key component of the EHT, formed by the most sensitive mm VLBI antennas in the World. A problem in the APP is the polarization calibration. The circular basis is used in VLBI, but ALMA observes in a linear basis. The strategy that will be followed in the phased-ALMA VLBI is to correlate in a "mixed" basis and convert to pure circular afterwards. We have developed an algorithm to perform the pol. conversion in the APP. The results of this algorithm, applied to realistic simulations, will be presented.

15:15 Tea/Coffee

Monday, 3 March

Session IV. SKA

16:00 **Stefan Wijnholds**. *A noise budget for SKA imaging applications*

Over the last few years, several people have made detailed analyses of potential limiting factors in deep imaging observations. It was also demonstrated how these factors can be mitigated by careful instrument design, a design for calibratability. In many of these presentations, only one effect is discussed in detail. In this talk, I present an overall noise budget for SKA imaging applications that allows to balance all contributions without exceeding a pre-specified limit on the effective noise floor in the image. I take the LFAA Element of the SKA as example, but the noise budget considerations apply equally to the other SKA Elements.

16:25 **Rik Jongerius**. *SKA phase 1 compute and power analysis*

In this talk I will present a compute model for the SKA phase 1 instruments. The model covers phased-array processing, the central signal processor, and the science data processor. I will focus on the SKA science data processor and discuss compute requirements for imaging with all baselines and the maximum bandwidth as specified by the SKA phase 1 baseline design. Combining the model with power-performance data extrapolated from the Top 500 supercomputer list, generates an envelope for feasible operating points of the instrument in the 2018 time frame if implemented on general-purpose computing platforms.

16:50 **Tim Cornwell**. *Contributing to SKA Calibration and Imaging - a Primer (remote)*

TBD

17:15 End of Day 1

17:30 – 18:00 Post-session drinks (provided) @ Blue Diamond Bar & Bistro

Tuesday, 4 March

8:30 – 9:00 Arrival tea/coffee with freshly baked Danish pastries

Session V. Imaging

9:10 **Ron Ekers**. *The evolution of indirect imaging in radio astronomy*

The early history of aperture synthesis imaging in Cambridge (UK) and in Sydney (Australia) including the methods used for computing the Fourier transforms followed by a brief discussion of the evolution of some of the imaging refinements such as deconvolution and adaptive calibration technique. I will comment on some of the interesting interactions between the groups involved, and between the astronomers, the X-ray crystallographers and the medical imaging practitioners.

9:35 **Sarod Yatawatta**. *ExCon: Making Billion Pixel Radio Interferometric Images*

Imaging a wide field of view with high enough resolution is needed for calibration and achieving a high dynamic range, especially with low frequency interferometers. We describe a new imager (ExCon) that is able to make widefield images that are far larger in size compared to images made by existing imaging software. In the process of implementing this new imager, we have also introduced a new algorithm in image weighting which will be described.

10:00 Tea/Coffee

10:45 **Keith Bannister**. *Memory efficient w-projection with the fast gauss transform*

We describe a method performing w-projection using the fast Gauss transform. We derive the theoretical performance and simulate the actual performance for a range of w for a canonical array. While our implementation is dominated by overheads, we argue that this approach could be the basis of higher performing algorithms with particular application to the Square Kilometre Array.

11:10 **Andrè Offringa**. *Imaging of MWA data with a new w-stacking imager*

A new interferometric imager is presented that uses the w-stacking algorithm and can make use of the w-snapshot algorithm. On MWA data, I find it to be an order of magnitude faster than w-projection, as well as being capable of full-sky imaging at full resolution and with full polarization correction. The performance dependencies of CASA's w-projection and WSClean are analyzed and analytical functions are fitted to the required computing cost for both imagers. Using these, the required computing cost for several other array configurations are predicted. I also show results of using the w-snapshot algorithm, which does not have a significantly further benefit.

Tuesday, 4 March

11:35 **Bill Cotton**. *A comparison of threaded CPU and GPU implementations of expensive interferometry operations.*

I will describe a comparison of multi-threaded CPU and GPU implementations of common, but compute intensive, operations in the analysis of radio interferometry data. This is part of an analysis of the general applicability of GPUs in radio astronomy data analysis. In particular, the extreme cases of a DFT based model calculation for which GPUs perform very well and visibility griding for which an efficient GPU implementation is challenging will be discussed.

12:00 **Ian Sullivan**. *Recent advances with Fast Holographic Deconvolution*

TBD

12:30 Lunch (provided) @ Restaurant 1871

Session VI. Primary Beams

14:00 **Mattieu de Villiers**. *Holography Python module for KAT-7 and MeerKAT*

This presentation outlines a few of the algorithms that are used for processing holographic measurements in both Ku and L-band for the SKA SA telescopes. A technique is discussed that does not necessitate the scanning antennas to accurately track in the boresight direction as is traditionally done periodically for gain calibration purposes. Instead, a model of the central part of the mainlobe is solved for whilst simultaneously solving for time-varying gain solutions. Frequency dependent beam squint behaviour, and aperture plane results for KAT-7 will also be reported.

14:25 **Kara Kundert**. *Modeling the Systematic Errors of ALMA Generated from Changes in the Primary Beam*

One of the major constraints on interferometric imaging is the ability to correct for the primary beam. At present, most arrays reconstruct images using a rudimentary model of the antenna apertures. With modern improvements in low-noise backend technology, these first-order approximations are beginning to generate the prominent errors in image reconstruction. This talk will review a simulation of ALMA, along with the effects of perturbed primary beam on simulated data and consider ways to correct these effects with current technical limitations.

Tuesday, 4 March

14:50 **Randall Wayth**. *Advanced MWA tile beam models*

Recent high quality observational data from the MWA has shown the our existing beam models, which were based on analytic results, are not accurate enough to explain the observed performance of the array. This talk provides an overview of new work that incorporates increased levels of realism in the beam model, in particular it explicitly incorporates mutual coupling effects and embedded element patterns to create much more realistic beam models. The polarisation response, in particular, is greatly improved.

15:15 Tea/Coffee

Session VII. Calibration

16:00 **Oleg Smirnov**. *TBD*

TBD

16:25 **Ian Heywood**. *TBD*

TBD, but probably something about automated "3rd generation" calibration of large JVLA data sets.

16:50 **Trienko Grobler**. *Ghost sources in WSRT data*

This work investigates a particular class of artefacts, or ghost sources, in radio interferometric images. Earlier observations with (and simulations of) the Westerbork Synthesis Radio Telescope (WSRT) suggested that these were due to calibration with incomplete sky models. A theoretical framework is derived that validates this suggestion, and provides predictions of ghost formation in a two-source scenario.

17:15 End of Day 2

17:30 – 18:00 Post-session drinks (provided) @ Blue Diamond Bar & Bistro

Wednesday, 5 March

8:30 – 9:00 Arrival tea/coffee

Session VIII. Compression and Bayes

9:10 **Slava Kitaeff**. *Data and Image Compression*

I'll talk about the applicability and impact of some data and image compression techniques on visibility and spectral-imaging data.

9:35 **Henrik Junklewitz**. *TBD*

TBD

10:00 Tea/Coffee

Session IX. Compressed sensing

10:45 **Ludwig Schwardt**. *Compressed Sensing for Radio Astronomers or: Why CLEAN Works*

The CLEAN algorithm and its variants have been in use in radio astronomy for several decades. While it has been very successful to date to improve synthesis image quality, the theory behind it has only recently become clear with the advent of compressed sensing. Compressed sensing exploits the sparsity of a signal to enable it to be reconstructed from a small number of measurements. This tutorial will introduce compressed sensing and show how it relates to CLEAN. It will discuss some popular reconstruction algorithms and show results on real astronomical data.

11:35 **Rafael Carillo**. *PURIFY: a new algorithmic framework for next-generation radio-interferometric imaging*

In recent works, compressed sensing (CS) and convex optimization techniques have been applied to radio-interferometric (RI) imaging showing the potential to outperform state-of-the-art imaging algorithms in the field. In this talk, I will review our latest contributions in RI imaging, which leverage the versatility of convex optimization to both handle realistic continuous visibilities and offer a highly parallelizable structure. This new algorithmic structure paves the way to significant acceleration of the reconstruction and scalability to large-scale imaging problems.

Wednesday, 5 March

12:00 **Jason McEwen**. *Revisiting the spread spectrum effect in radio interferometric imaging: a sparse variant of the w-projection algorithm*

Next-generation radio interferometric telescopes will exhibit non-coplanar baseline configurations and wide field-of-views, inducing a w-modulation of the sky image, which induces the spread spectrum effect. We revisit the impact of this effect on imaging quality and study a new algorithmic strategy to deal with the associated operator. In previous studies it has been shown that image recovery in the framework of compressed sensing is improved due to this effect, where the w-modulation can increase the incoherence between measurement and sparsifying signal representations. For the purpose of computational efficiency, idealised experiments with a constant baseline component w were performed. We extend this analysis to the more realistic setting where the w-component varies for each visibility measurement. Firstly, incorporating varying w-components into imaging algorithms is a computational demanding task. We propose a variant of the w-projection algorithm, which is based on an adaptive sparsification procedure, and incorporate it in compressed sensing imaging methods. Secondly, we show that for varying w-components, reconstruction quality is significantly improved compared to no w-modulation, reaching levels comparable to a constant, maximal w-component. This finding confirms that one may seek to optimise future telescope configurations to promote large w-components, thus enhancing the fidelity of image reconstruction.

12:30 Lunch (provided) @ Restaurant 1871

14:00 Buses leave for bushwalk @ Minnamurra rainforest.

17:30 Buses arrive back to the hotel. End of Day 3.

Thursday, 6 March

8:30 – 9:00 Arrival tea/coffee

Session X. Imaging & Calibration

9:10 **Sanjay Bhatnagar**. *Projecting-out the frequency and polarization dependent instrumental effects: Some thoughts and results (remote)*

Sky signals carry astrophysically important (and often times unique) information in the radio band. We therefore also explicitly incorporate frequency and polarization dependence of the sky brightness distribution in the deconvolution process to extract the necessary scientific information. In this talk, I will discuss the need for projecting-out the frequency and polarization dependence of antenna Primary Beams (including off-axis frequency and polarization effects) prior to or during imaging to accurately derive these astrophysically important information, uncorrupted by instrumental effects. Algorithms attempting to separate these instrumental effects from the astronomical signal during deconvolution are non-optimal in the theoretical sense with real measurable effects in terms of the degradation of the imaging performance as well as in the inaccuracy of the derived astrophysical information. These degradation and inaccuracies worsen for wide-band mosaic imaging, are significant (much higher than thermal noise limits) for even current operational telescopes and may be limiting for SKA-class telescopes. I will show a few results – from careful simulations and from application to real wide-band data from the EVLA, and describe the work our group is engaged-in in this area now and what we will be doing in the near future.

9:35 **Urvashi Rau**. *How accurately do our imaging algorithms reconstruct intensities and spectral indices of weak sources? (remote)*

A large number of deep and wide-field radio interferometric surveys are being designed to measure accurate statistics of faint source populations. Most require mosaic observations, and expect to benefit from the sensitivity provided by broad-band instruments. In this talk, I will evaluate and compare several wideband imaging methods in the context of how accurately they reconstruct the intensities and spectral indices of micro-Jy level sources. Their relative computational costs will also be discussed.

10:00 Tea/Coffee

Thursday, 6 March

Session XI. Calibration

10:45 **Tammo Jan Dijkema**. *Calibration and Imaging Tiger Team: Improving LOFAR calibration and imaging.*

The calibration and imaging tiger team (CITT) is developing improvements to the imaging pipeline for the LOFAR radio observatory. In this talk we give an overview of the LOFAR imaging pipeline, and present some results of the CITT on several segments of it. We present preliminary results on speeding up direction independent calibration using stefcal. Also we give an overview of the improvements and plans on the AWImager.

11:10 **Nicolas Vilchez**. *Calibration and Imaging Tiger Team: Phase screen fitting and SelfCal*

The calibration and imaging tiger team (CITT) is developing improvements to the imaging pipeline for the LOFAR radio observatory. In this talk we show results on direction dependent ionospheric calibration, including the use of phase screens applied directly during the imaging process. We conclude with progress on the self-calibration segment of the imaging pipeline and demonstrate the improvements obtained in typical images.

11:35 **Cyril Tasse**. *A new calibration algorithm using filtering and regularization techniques*

We present a new calibration scheme based on a non-linear version of Kalman filter. Using this algorithm, we can potentially reduce the number of free parameters by orders of magnitudes while dramatically increasing the size of usable data. Recursive algorithms are particularly well adapted for pre-calibration and sky model estimate in a streaming way.

12:00 **Stefano Salvini**. *Calibration with StEFCal: progress, advances and successes*

This talk provides an overview of the latest StEFCal developments. The fully polarized algorithm has been completed, including solution for convergence issues. Different versions of the algorithm will be discussed and can be made available. Their performance and implementations will be discussed, in particular with respect to SKA. StEFcal is now being used for LOFAR stations calibration, as well as Superterp, within Meqtrees and within NDPPP. Further developments are aimed at smoothing within a time-frequency interval, by polynomials or otherwise, and steps towards demixing.

12:30 Lunch (provided) @ Restaurant 1871

Thursday, 6 March

Session XII. Polarization and Ionosphere

14:00 **Tobia Carozzi**. *Sensitivity of dual polarized feeds*

In radio astronomical imaging total sensitivity is a crucial parameter. But despite the fact that most modern radio telescopes are dual polarized the impact of this feature on sensitivity is usual trivialized. Indeed one usually assumes that the two polarization channels have identical gains and there is negligible leakage between them. In this presentation, I show a more realistic model of dual-polarized feeds and derive how this affects total sensitivity and polarized sensitivity even after full polarimetric calibration.

14:25 **Tony Willis**. *Prediction and Correction of Ionospheric Faraday Rotation Measures using Ground-based Observations of GPS Satellites*

Low frequency radio astronomy is booming. There are a number of new low frequency telescopes that are either coming on line (LOFAR, MWA) or are in the building and planning stage (ASKAP, MEERKAT, LWA, SKA1, CHIME). One of the goals of many of these telescopes is the study of cosmic magnetism. Much of the information about cosmic magnetism is carried in the polarized component of the incoming radio waves and how the polarized component changes as a function of wavelength due to Faraday rotation (RM). However in order to properly study the RM associated with celestial radio sources we must remove that part of the RM due to the Earth's own ionosphere. While a Postdoc at ASTRON, James Anderson developed a software package to predict and remove ionospheric Faraday Rotation Measure effects as part of the European Community funded project called ALBUS (Advanced Long Baseline User Software). This package determines ionosphere total electron content (TEC) and RM from ground based observations of GPS satellite signals. We have enhanced and extended this package so that it should be usable with any low frequency radio telescope. We describe the current status of the package and compare the corrections for ionosphere RM determined by the ALBUS software with those predicted by other software systems.

Thursday, 6 March

14:50 **Balwinder Arora**. *Calibration of Ionosphere Faraday Rotation for Low Frequency Arrays*

The radiation from a distant astronomical source propagates in a medium of free charged particles, ions and electrons induced with magnetic field. Due to the presence of electrons in the ionosphere, the phase is advanced which is observed as a position shift in the data. This is also known as first order ionosphere effect and accounted as Dispersion Measure (DM). Further due to presence of magnetic field along with the charged particles, phase experiences rotation based on its characteristic polarisation. This effect is called as Ionosphere Faraday Rotation (IFR) and can be accounted by using the Rotation Measure (RM). The first order ionosphere delay is proportional to ν^{-1} and the second order Faraday Rotation is proportional to ν^{-2}. Faraday Rotation effect increases in magnitude lower the observing frequency. ASKAP is operating in the frequency range of 700 MHz to 1.8 GHz, MWA operates between 80 to 300 MHz and the future SKA-low will be operating in the frequency range 70 to 450 MHz. At 100 MHz, 1 rad m^{-2} of RM would produce a rotation of 9 radians in Polarisation Angle (PA). In view of the current and future developments, it hence becomes important to accurately account for IFR in the radio astronomy observations. This presentation discusses the computation and calibration of IFR for low frequency arrays.

15:15 Tea/Coffee

16:00 Conference Summary

18:00 Bus leaves for conference dinner at Altitude 1148 restaurant

22:40 Bus returns to the hotel. End of Day 4

Friday, 7 March

8:30 – 9:00 Arrival tea/coffee

Additional discussions (SKA SDP, PAF and beam de-rotation, any other topic raised during the conference)

10:00 Tea/Coffee

Additional discussions (SKA SDP, PAF and beam de-rotation, any other topic raised during the conference)

12:30 Lunch (provided) @ Restaurant 1871

Additional discussions (SKA SDP, PAF and beam de-rotation, any other topic raised during the conference)

15:15 Tea/Coffee

Additional discussions (or go home if we're bored)

16:20 The end