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ASKAP Science Update

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The ASKAP Science Update is a regular series dedicated to conveying the latest news about the Australian SKA Pathfinder (ASKAP) project to the international science community. It is also available online at www.atnf.csiro.au/projects/askap.

Preparing for first BETA Observations with ATCA

As part of preparations for BETA (Boolardy Engineering Test Array), the ASKAP Project Scientist and members of the Survey Science Teams began characterisation of two 30 deg^2 fields during two separate week-long ATCA observing sessions during May and June.

BETA is an array of the first six ASKAP antennas installed with Phased Array Feed (PAF) receivers at the Murchison Radio-astronomy Observatory (MRO) in Western Australia.

Although primarily an engineering and scientific commissioning instrument, early astronomy observations may be possible with BETA once the instrument is fully tested and during times when it is not otherwise required for commissioning activities.

Characterisation observations took place using CSIRO's Australia Telescope Compact Array (ATCA) during May and June, by Ilana Feain and Simon Johnston together with members of the ASKAP Survey Science Teams.

According to ASKAP Project Scientist Ilana Feain, the two fields were chosen, for very specific reasons, in consultation with the Principal Investigators of the ten ASKAP Survey Science Projects (SSPs).

"The fields were purposefully chosen for content and location – approximately 12 hours apart on the sky – so that no matter what time of day or night we are able to use BETA, there will be a fully characterised field available to initiate science verification," says Ilana.

"When we observe these first science fields with BETA for the first time, we want to compare our results with what we *know* we should see, in order to test data quality and integrity of the system."

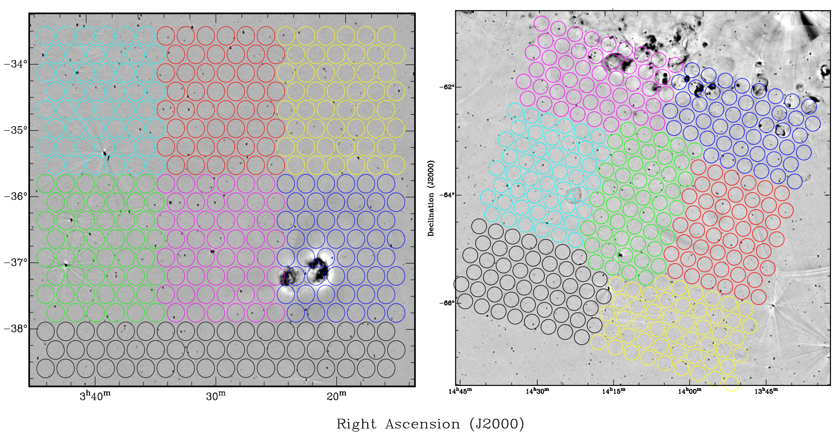
One of the chosen fields is centred close to NGC 1365 in the Fornax cluster, the other is centred close to the Circinus galaxy. Previous multi-wavelength surveys on small regions within each of these fields make them the perfect candidates for observation because much is already known. Both the Fornax cluster and Circinus have been extensively mapped in neutral hydrogen (HI) and 20cm radio continuum, and the radio galaxy Fornax A has been studied in polarisation and radio continuum both at ATCA and the Very Large Array (VLA).

Despite the level of detail already available for certain parts of the two fields, the aim of the characterisation was to achieve a 30 deg^2 field at equivalent angular and spectral resolution and sensitivity and frequency of BETA.

The team was allocated 14 full days of ATCA observing time, and observations were run 24 hours a day over two separate seven-day blocks – 12 hours each for Fornax and Circinus – in two array configurations (750b and 1.5b) that together closely match the uv-coverage of BETA.

The two fields shown here, from the Sydney University Molonglo Sky Survey (SUMSS), are overlaid with a set of coloured circles representing the daily ATCA pointings required to mosaic the full region. BETA will cover each of these regions in its single 30 deg^2 field of view.

"These images will allow us to test BETA calibration and imaging pipelines, allow for verification and refining of the source finding and cataloguing techniques, in addition to a range of data quality tests," explains Ilana. "These two fields act as our control fields against the unknown and possibly variable calibration systematics of a new telescope."



> The two fields chosen as 'first science with BETA' characterisation fields. The left is centred on the Fornax cluster and contains the bright extended radio galaxy Fornax A (bottom right). The right is centred on the barred spiral Circinus galaxy and contains extended emission from the Milky Way (top right). Both images are shown at 843MHz from the Sydney University Molonglo Sky Survey (SUMSS) overlaid with a set of coloured circles representing the daily ATCA pointings. Credit: Ilana Feain.

"The combination of features that makes ASKAP so unique is also what makes FLASH possible."

ASKAP Survey Science Projects

In this edition of *ASKAP Science Update* we take a detailed look at the final two of the ten Survey Science Projects (SSPs) that will make use of ASKAP during its first five years of operation.

FLASH

Sensitive observations of distant galaxies have made it possible to map out the star-formation history of the Universe in detail, yet almost nothing is currently known about the distribution of the cold neutral gas from which these distant stars are formed.

Radio emission surveys give some clues to this, by detection of weak neutral hydrogen (HI) at lower redshift, yet current day radio telescopes are stretched to their limit beyond z = 0.1, leaving almost 80% of cosmic time unexplored in HI.

The vast collecting area of the Square Kilometre Array will open up an entirely new vista of the early universe, but some astronomers, such as those involved in the First Large Absorption Survey in HI (FLASH), are not content to wait until the SKA is built to probe galactic content at low redshift.

As Principal Investigator (PI), Elaine Sadler will lead the FLASH project, a blind HI absorption-line survey using ASKAP that uses background radio continuum sources to identify and characterise foreground neutral hydrogen. Absorption surveys have the advantage that detection sensitivity depends only on the brightness of the background radio source, rather than the distance to the intervening galaxy.

This will allow the team to study HI in galaxies at much larger distances than emission-line surveys, and provide a significant dataset to study gas assembly and galaxy formation during a time in history of the Universe which has been left largely unstudied thus far.

As Elaine explains, FLASH will break new ground in low redshift investigation, whereas existing radio telescopes have reached the limits for HI studies.

"Blind HI absorption surveys are not possible on current-day radio telescopes due to limitations in spectral bandwidth, RFI and survey speed. The combination of features that makes ASKAP so unique, in particular the wide field-of-view and spectral bandwidth, is also what makes FLASH possible."

Rapid sky coverage will be essential for FLASH. With 150,000 sightlines planned (that's 375 times the number of sightlines to bright continuum sources that have been searched over the last 30 years), approximately only 1% are expected to yield strong HI absorption, so the team will need to extract around 150 radio spectra from each ASKAP field for testing.

Additionally, as FLASH will focus on a lower range of frequencies (700 – 1000 MHz), it would be highly susceptible to terrestrial radio interference. The radio-quiet environment of ASKAP's home at the Murchison Radio-astronomy Observatory (MRO) in Western Australia is therefore the perfect place for FLASH.

Though Elaine describes the project as 'observationally simple', the main challenge facing the FLASH team will be data interpretation, and the plan to reconstruct a whole galaxy from just the small piece that they will see.

"We already know the positions of the target sources, since these are in existing catalogues of the radio sky made by earlier surveys," she explains. "Unlike an emission-line survey, where we would map the whole galaxy, absorption-line surveys only give us information on a single small sightline that runs through a galaxy."

To overcome the challenge, once an absorption line is detected, follow-up optical and CO emission measurements will be made with other telescopes like the AAT and ALMA.

There is also scope for high levels of collaboration between FLASH and the other ASKAP SSPs, especially WALLABY and DINGO. "Since our current knowledge is so incomplete, anything we can learn about gas in distant galaxies will be useful in planning and preparing for the SKA," says Elaine.

"The WALLABY and DINGO surveys will provide us with rich HI data sets which will certainly provide new insights into the gas content of galaxies. Similarly, the information we expect FLASH will produce may complement these surveys by providing our first look at the HI properties of galaxies in the unexplored redshift range beyond z = 0.5"

She concludes, "HI absorption-line surveys covering large areas of sky have never been possible before. What's most exciting to me is that ASKAP's unique ability to cover the sky rapidly and observe many bright sources at once will allow us to extend our study of HI in galaxies out to a cosmic epoch, around five to eight billion years ago, which is completely unexplored until now."

>Elaine Sadler, Principal Investigator of FLASH. Credit: Keith Shortridge.

CRAFT

The lure of the unknown is a common theme in astronomy, and for the Commensal Real-time ASKAP Fast Transient (CRAFT) survey, it is what drives the team.

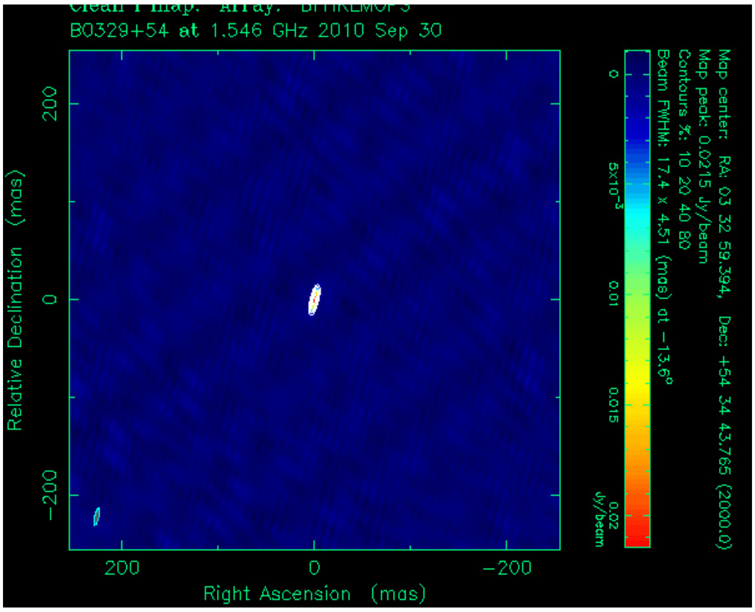
CRAFT will operate in tandem with other ASKAP SSPs, collecting and processing data in real-time in order to search for signals that appear for less than milliseconds at a time. There are a number of possible objects that may be detected (such as giant pulses, rotating radio transients, magnetars, even SETI signals), but CRAFT is not yet playing favourites.

For Principal Investigator Peter Hall, the appeal of CRAFT lies in the open ended nature of the challenge, describing it as a "systematic exploration of uncharted parameter space."

Fast transient signals are associated with the most energetic and brightest single events in the Universe, with emission generated by matter under extreme conditions that cannot be replicated terrestrially.

"These signals open up the physics of high brightness temperature objects, extreme states of matter and strong gravitational fields," says Peter, "and detection of extragalactic transients would give us an entirely new probe on the huge reservoir of baryons in the intergalactic medium."

>Peter Hall, Principal Investigator of CRAFT. Credit: ICRAR.



>An image from V-FASTR, showing one pulsar pulse identified via an incoherent rocessing path and a machine-learning algorithm, a possible technique that could solve the challenge of data processing with ASKAP. Credit: CRAFT / ICRAR.

In preparation for observing with ASKAP, the CRAFT team must assess the likely scientific productivity of different areas in observing space, engineering trailblazer scientific instrumentation and conducting observations using the most capable existing telescopes. This requires the development of hardware, algorithms and personnel necessary to harness ASKAP's capabilities.

The CRAFT team believes that new transient detections with ASKAP are almost a certainty, for if a sizable fraction of the information provided from such a widefield instrument can be exploited at high time resolution, it may probe extremely rare short-lived phenomena, even down to event rates of a few per day across the sky.

"The wide field of view of ASKAP is very important to us, but so is the spatial diversity of the array" Peter explains. "The field of view of a single dish like Parkes is too large to pinpoint the origin of a cosmic transient, but by using the widefield interferometric capabilities of ASKAP, we can localise events while, at the same time, anticipate an event rate of typically 35 times that the Parkes Multibeam system."

Trailblazer activity, such as the V-FASTR project (the VLBA fast transient project), is already underway using the US Very Long Baseline Array, which allows the team to investigate the challenge of detection methods and data processing.

The sheer amount of data collected while searching for short timescale events with a survey instrument such as ASKAP is compounded by the need to process data in real-time, before it reaches the correlator and without impacting primary ASKAP observing by other SSPs.

"Even the most basic observing sessions will produce data rates of 10Gb/s," says Peter. "We must investigate and implement a variety of data aggregation techniques to determine the most suitable processing method.

Once achieved, this offers the added benefit of demonstrating how to deal with large data rates, and provides proof-of-concept for SKA-related technologies."

While some of the other preliminary ASKAP SSPs concentrate on 'teaching' post-processing computers to recognise known events, early CRAFT outcomes will contribute new information to the as-yet poorly understood science of cosmic transients, with event verification and localisation central to the science goals.

"We only have tantalizing glimpses of the transient Universe," Peter says, "the great majority of the multi-dimensional observing parameter space remains uncharted territory."

International SKA Forum 2011

A delegation of representatives from Australia–New Zealand, including members of CSIRO's ASKAP team, recently attended the International SKA Forum 2011 and associated meetings on either side of 'SKA Week' in Banff, Canada.

The A–NZ delegation included senior representatives from the Australian, New Zealand and Western Australian Governments and several SKA scientists and industry representatives.

SKA Project Director for Australia–New Zealand Dr Brian Boyle led the anzSKA presentation, with contributions from CSIRO SKA Project Scientist Dr Lisa Harvey-Smith and ICRAR Deputy Director Professor Steven Tingay.

The team focused on a collaborative theme, *Supporting the Big Picture*, and the A–NZ presentation included a short *Welcome to Country* film depicting the beauty and history of the region around the Murchison Radio-astronomy Observatory (MRO).

For more information: www.ska.gov.au

> Representatives from the Australia–New Zealand SKA team at Banff, Canada. Credit: Ben Scandrett, Department of Innovation, Industry, Science and Research.

Forthcoming Meetings

Members of the ASKAP team will be attending a number of upcoming scientific meetings:

- Asia Pacific Microwave Conference
  Melbourne, Australia
  5 – 8 December 2011
- 219th AAS (American Astronomical Society) Meeting
  Austin, USA
  8 – 12 January 2012
- IAU Symposium 287: Cosmic masers - from OH to H_0
  Stellenbosch, South Africa
  29 January – 3 February 2012

If you would like to find out more or have questions about ASKAP please don't hesitate to find us, we look forward to meeting you.

For further information:

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