ASKAP Commissioning Update #7
April-July 2014

Welcome to the seventh edition of the ASKAP Commissioning Update. This includes all the latest results from commissioning of the six-antenna ‘Boolardy Engineering Test Array’ (BETA). We hope you enjoy receiving this regular update on the progress of ASKAP commissioning. Don’t hesitate to contact us if you have any questions.

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ASKAP Project Director

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Latest results from the BETA test array

Simultaneous pulsar monitoring and Galaxy mapping

Ian Heywood has demonstrated the versatility of ASKAP and BETA with this impressive new image shown in Figure 1. The target was an intermittent pulsar located in region A. Splitting the data into 390 snapshot images, each formed from two minutes of data, revealed that BETA can detect the pulsar entering its active state on three separate occasions during the observation. These events were confirmed by a simultaneous observation with the Parkes telescope - thus demonstrating the capabilities of BETA for observing transient phenomena.

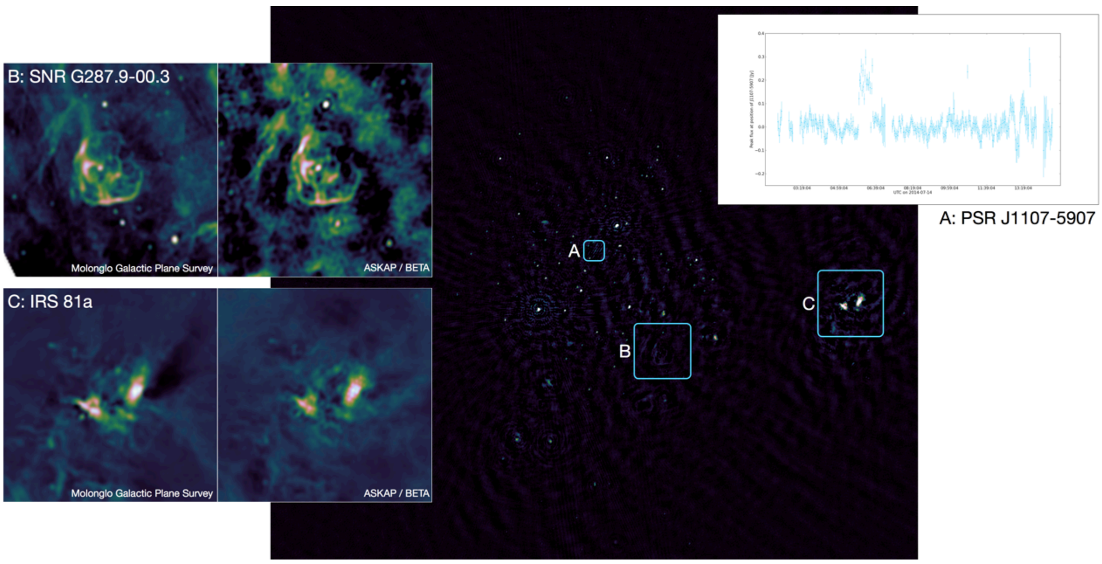

Figure 1: BETA image from a single beam showing a region of the Galactic plane and the light-curve of a variable pulsar derived simultaneously from the data. It was made from 13 hours of data between 0.7 – 1 GHz. Credit: I Heywood/ACES team, CSIRO.

ASKAP will be a wide field survey machine, and even when targeting a single source with BETA a significant swath of the sky comes for free. BETA can see with impressive detail many morphologically interesting features in the galactic plane, with insets B and C comparing the BETA images to those from the Molonglo Galactic Plane Survey. It is noteworthy that IRS 81a is imaged through the first sidelobe of the boresight BETA beam, three degrees away from the field centre. Producing an image of this quality without the rotational third axis of the telescope would likely be impossible.

HI Velocity Fields of Nearby Galaxies

This month, Paolo Serra demonstrated the first multi-beam observation of extra-galactic HI with BETA.

Figure 2 shows a preliminary image of a HI velocity field obtained from a nine beam BETA observation of a region of the sky including two galaxies, NGC 253 (south) and NGC 247 (north), which are 4.5 degrees apart. Nine beams were arranged in a straight line covering the full length of the PAF field of view in order to observe both galaxies at once.

Data were processed in MIRIAD after initial flagging with ASKAPsoft. A bandpass calibration was carried out using the standard calibration source B1934-638. The noise in the 9-beam mosaic cube is 13.5 mJy/beam in a 15.5-km/s-wide channel.

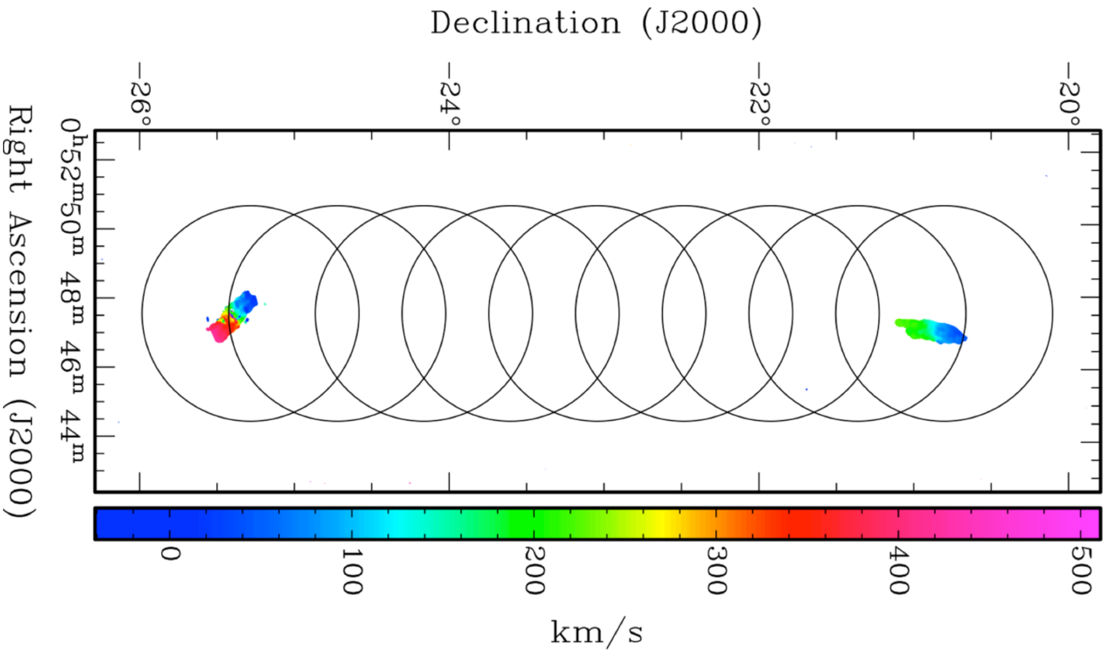

Figure 2: A preliminary nine-beam BETA image showing the neutral hydrogen velocity fields of two nearby galaxies NGC 253 and NGC 247. Credit: P Serra/ACES team, CSIRO.

This follows the first single-beam HI velocity field imaging results for NGC253, which were released in an ASKAP News story in June 2014 on the ATNF news website http://www.atnf.csiro.au/projects/askap/news_commissioning_11062014.html and reported in the media.

Exploring 7.7 Billion Years of Neutral Hydrogen

The HI line seen in absorption against a bright compact radio source is a powerful probe of the kinematics of neutral gas in galaxies to high redshift. James Allison and other members of the FLASH survey science team have been carrying out demonstrations of HI absorption science using BETA.

The spectrum in Figure 3 was obtained from an observation of the 1 Jy radio galaxy PKS2252-089 using the 712-1015 MHz band of BETA. The absorption line associated with HI gas intrinsic to PKS2252-089 was discovered by Curran et al. (2011) using the GBT (http://arxiv.org/abs/1012.1972) and can clearly be seen at 884 MHz. This spectrum demonstrates the excellent capability of ASKAP for carrying out the future all-sky First Large Absorption Survey in HI (FLASH).

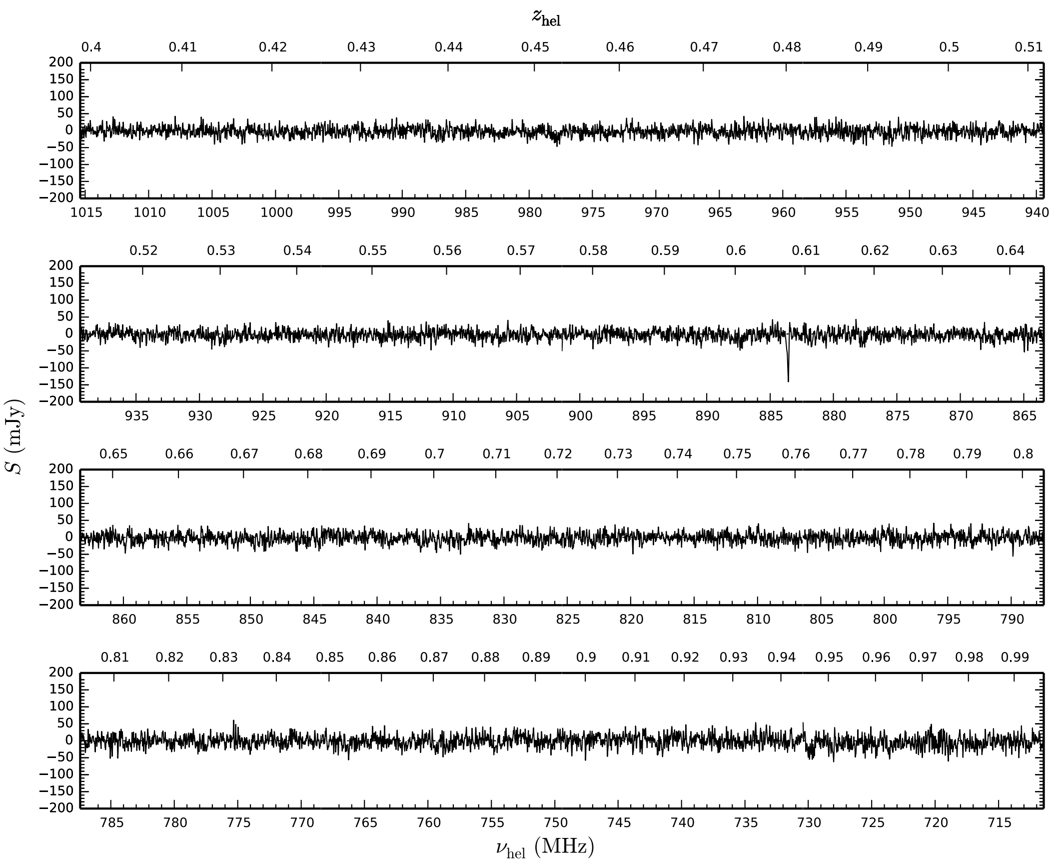

Figure 3: Spectrum towards the 1Jy radio galaxy PKS2252-089 taken with BETA. The known intrinsic HI absorption line can be seen at 884MHz. The data have been automatically flagged for birdies and other narrow-band RFI, and further Hanning smoothed to improve the visibility of the HI line. *The noise rises slightly towards the lower frequency end of this spectrum as expected. Credit: James Allison/ACES team, CSIRO.*

Investigation of Polarisation

Bob Sault has been investigating the polarisation response of the BETA array to polarised and unpolarised astronomical radio sources.

Figure 4 shows the frequency variation of the polarization position angle of 3C138. The green line is a model fit. This gives an intrinsic polarization angle of -9 degrees and rotation measure of -2.4 rad/m^2, which are consistent with prior estimates. The data were corrected for ionospheric Faraday rotation using a publicly available database of routine global GPS measurements of the ionosphere and the "ionFR" software described in Sotomayor-Beltran (2013). The ionospheric RM was typically ~3 rad/m^2 during the observation.

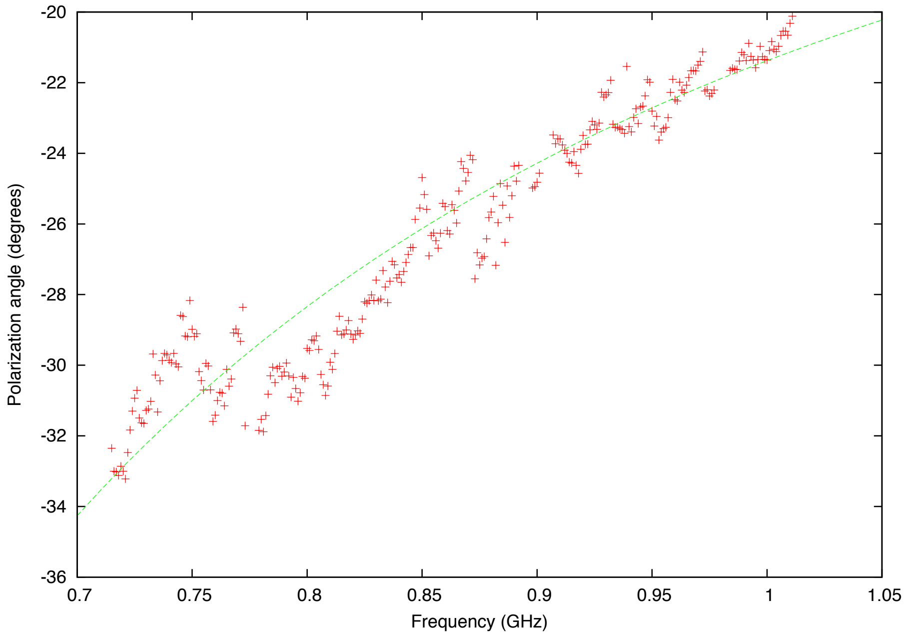

Figure 4: Measured frequency variation of the polarisation position angle of 3C138 (symbols) and a model fit. Credit: Bob Sault/ACES team, CSIRO.

Figure 5 shows I,Q,U,V images of 1934-638. The top left is Stokes I with a greyscale range of +/- 100 mJy/beam. The bottom right is Stokes V with range of +/- 2 mJy/beam. The other two are Stokes Q and U with range of +/- 5 mJy/beam.

1934-638 is about 13.6 Jy in Stokes I, but unpolarised to 1 part in 100,000, so nothing is expected for the source in the Q,U,V images. But some background sources are apparent in the 1934 field in Q and U. The polarimetric dynamic range is about 1 part in 7000 near the field centre.

These data are from the single central formed beam, and with 300 MHz of data (some background sources are no doubt Faraday depolarized away in the Q and U images).

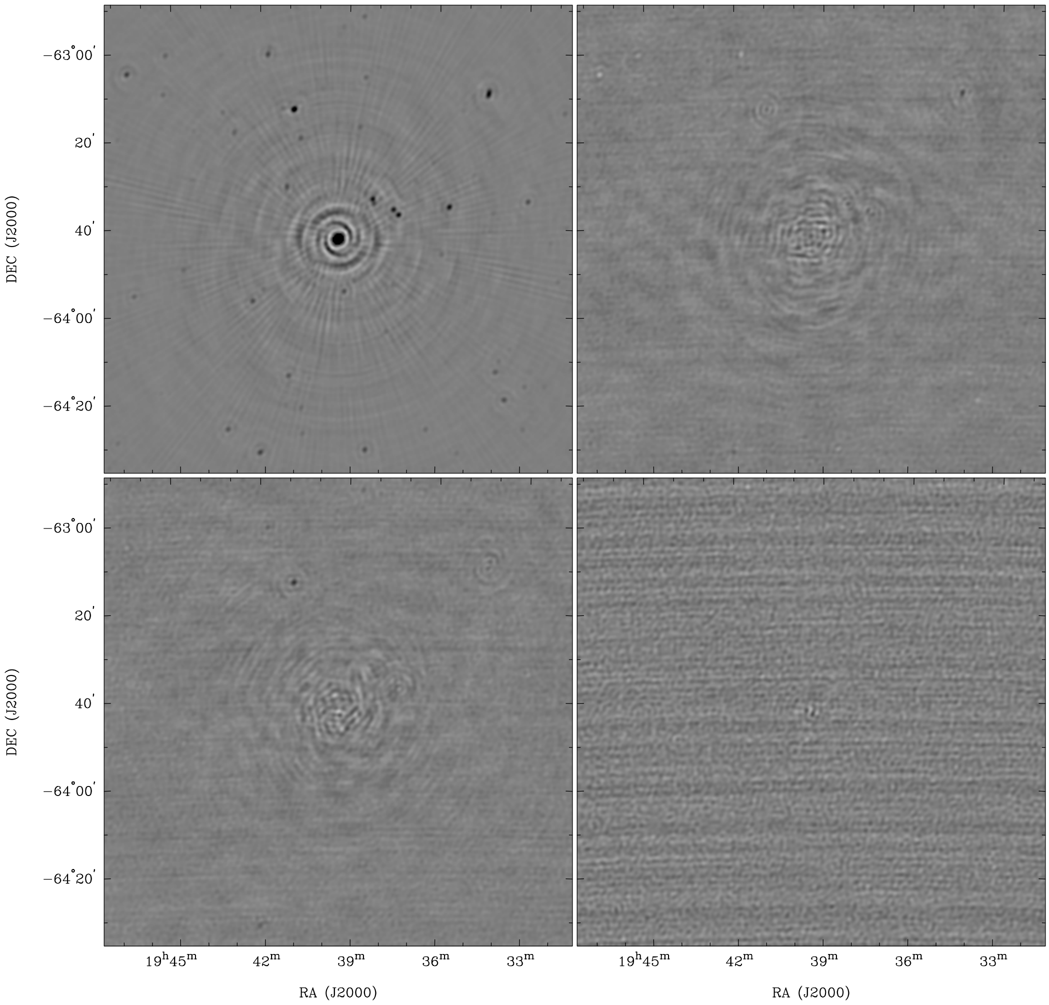

Figure 5: Top left to bottom right - Stokes IQUV images of B1934-638 from BETA. Credit: Bob Sault/ACES team, CSIRO.

Optimising Calibration and Imaging Strategies for PAFs

Martin Bell has been investigating the optimum calibration, cleaning, imaging and averaging strategy for phased array feeds with multiple beams. Figure 6 compares the CLEAN map resulting from the process of imaging, deconvolving and averaging data from 9 PAF beams centred on B1934-638 using two different calibration strategies. The unusual diamond beam arrangement was designed specifically for imaging tests of this field. The image in Figure 6 (left) was made using a model containing a single point source at the centre of the image (with the calibration solution applied to all other beams). The image on the right used a sky model containing several bright sources in the field. The calibration of the off-axis beams has not yet been optimised but is a work in progress.

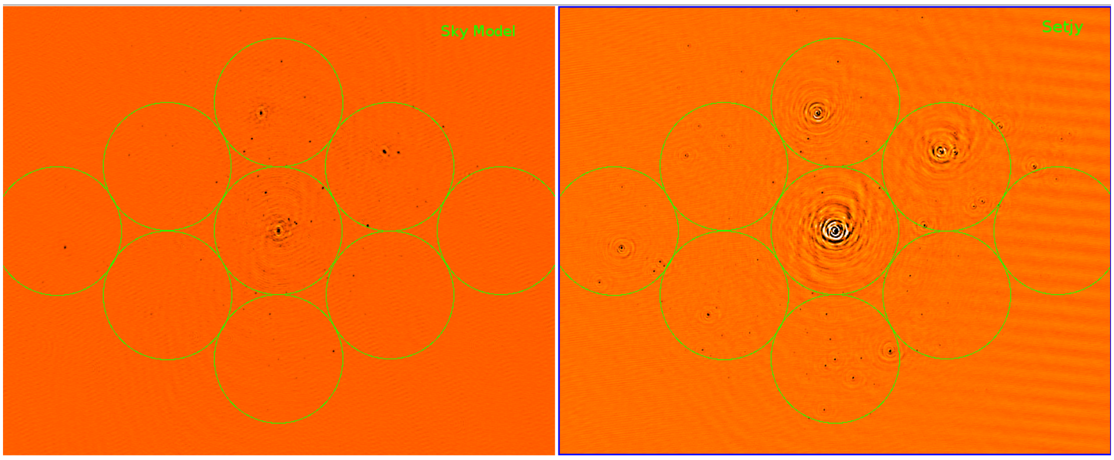

Figure 6: The image on the left was made using a model containing a single point source at the centre of the image. The image on the right used a sky model containing several bright sources in the field. The colour scale has been inverted for clarity. The images have been cleaned but the calibration and averaging of the off-axis beams has not yet been optimised. Credit: Martin Bell/ACES team, CSIRO.

A Survey of RFI Using BETA

Lisa Harvey-Smith and Balt Indermuehle are investigating the spectral environment of the Murchison Radio-Astronomy Observatory using the BETA array. They have begun a systematic survey that will enable them to investigate the spectral occupancy across the full ASKAP band as a function of direction, baseline and time.

Preliminary plots of visibility amplitudes in frequency-time space reveal a range of expected spectral features including the broadband lines from satellites above 1 GHz. Spatial filtering techniques for RFI mitigation are being developed in parallel with this measurement campaign (see the next section for details) to mitigate their effect on data. There is a very low level of RFI in the 700-1000 MHz band (Figure 7), which looks particularly promising for the exploration of redshifted HI using ASKAP and SKA1_survey. The comb of narrow-band features visible towards the left of Figure 7 originates from a microprocessor in the BETA cooling system that has been eliminated from the ASKAP system design.

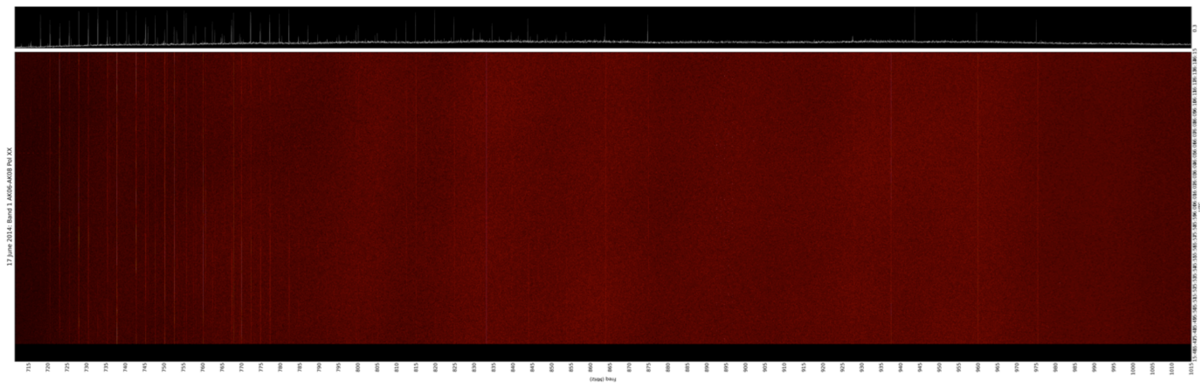

Figure 7: Frequency-time visibility plot showing very low levels of RFI in a typical observation in the 700-1000 MHz band using BETA. The 'comb' of narrow features (left) originates from the BETA cooling system. This will not be present in the ASKAP spectrum. Credit: Lisa Harvey-Smith, Balt Indermuehle/ACES team, CSIRO.

RFI Spatial Filtering using PAFs

The spatial information provided by ASKAP's Phased Array Feed (PAF) can be exploited for interference mitigation purposes and Greg Hellbourg is working on techniques to achieve this. The main advantage of the spatial approach is that it theoretically allows the perfect recovery of the data of interest in the time-frequency domain. To achieve this goal, the first step of spatial RFI mitigation is to estimate the RFI spatial signature. Once estimated, the RFI spatial signature is used to project the RFI contribution out of the data.

The RFI spatial signature estimation accuracy can greatly be improved with the use of *a priori* information provided by a reference antenna. To show this, an observation was performed with a 12 m dish at Parkes as well as a fast 3.7 m reference dish antenna in the Galileo satellites frequency band (Figure 8).

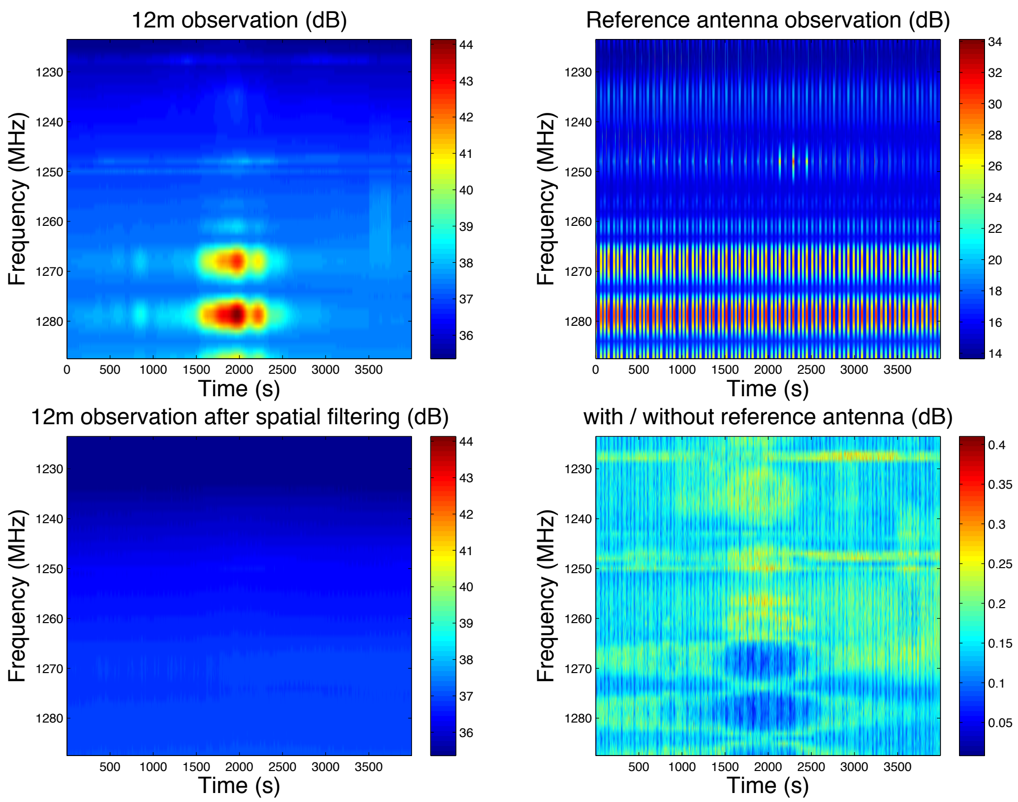

Figure 8. Top left: Time frequency plot of data from the Parkes 12m test dish. Three satellites with known orbits are corrupting the observation, but only one satellite is clearly visible as it crosses the primary beam. Top right: Time frequency plot of the data recorded with the reference antenna as it looped over the three satellites. Bottom Left: *The processed time frequency plane, made by estimating the satellites' spatial signatures and projecting their contributions out. Bottom right: The residual difference of a spatial filtering using the reference antenna and the classical approach based on the Array Covariance Matrix only. Credit: Greg Hellbourg, CSIRO.*

The reference antenna approach really improves the spatial filtering performances for low interference-to-noise ratios. Further observations with different RFI scenarios will be performed to evaluate the sensitivity and the steadiness of the method.

VLBI with a phased array feed on ASKAP

The VLBI team led by Chris Phillips has carried out the first demonstration of VLBI using a phased array feed. Figure 9 shows an image of 0537-441 made with data from the Australian long baseline array - with and without the inclusion of data from a single ASKAP antenna. The other antennas were Parkes 64m, the phased ATCA, Mopra and Ceduna.

The ASKAP data were captured as raw voltages after the beam former. The 1.18 MHz coarse channels were filtered and merged to produce a single 16 MHz Nyquist sampled band, which was correlated with the DIFX software correlator.

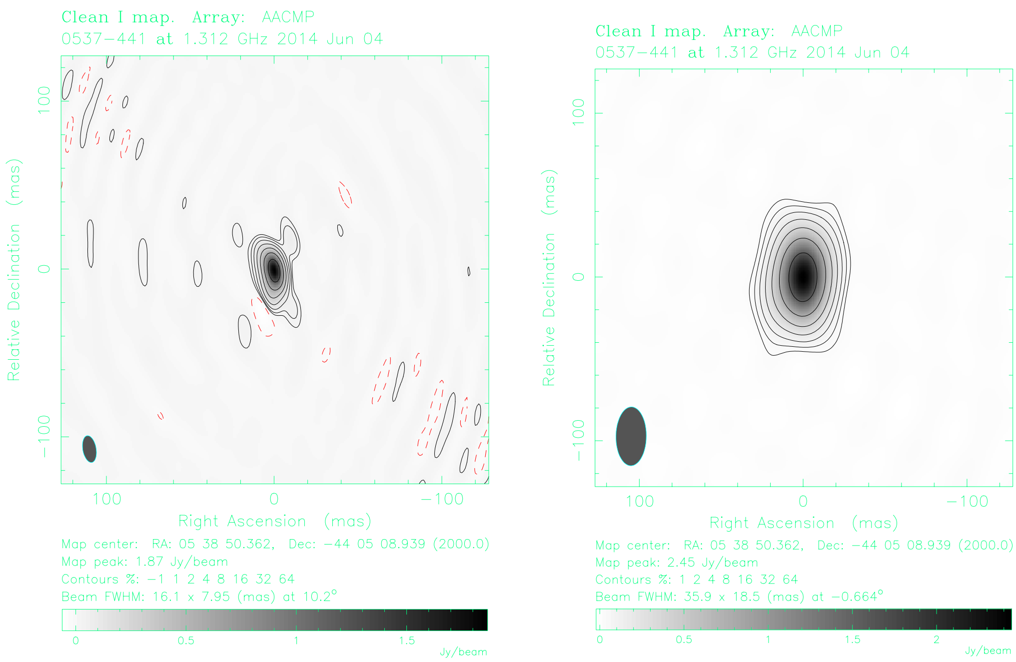

Figure 9: Total intensity image of 0537-441 using the Australian Long Baseline Array, (left) with a single ASKAP antenna and (right) without ASKAP. Credit: Chris Phillips, CSIRO.