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Reader's Digest

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Publication stories about
CAASTRO research

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CAASTRO Education & Outreach

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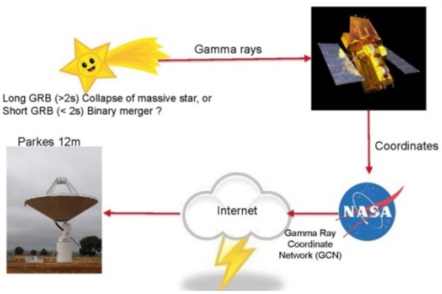
Do gamma-ray bursts produce Lorimer bursts?

Since Lorimer et al. (2007) reported the detection of a single short and bright radio burst that could be traced back to extragalactic origin, astronomers have tried to come up with plausible models to explain the observation and have conducted surveys to detect more of these peculiar signals. While we are still lacking a good model, CAASTRO's ex-PhD student and now CSIRO Bolton Fellow Keith Bannister and his CAASTRO and CSIRO co-workers might have found the mechanism that produces the phenomenon.



In their paper (The Astrophysical Journal 757), they present a thorough examination of nine months of radio data collected immediately after the detection of gamma-ray bursts by the Swift satellite. Out of nine observed gamma-ray bursts, Bannister et al. found that two produced single-radio bursts that satisfied their stringent analysis, taking into account the possible contamination through radio frequency interference. Unless these observations can be repeated with a different telescope, radio interference remains difficult to rule out.

Having drilled further down into the data, the research team could conclude that the pulses are not due to random noise fluctuations at 95% confidence (assuming Gaussian noise) and 97% confidence (running a null trial of randomised channels in their data processing).

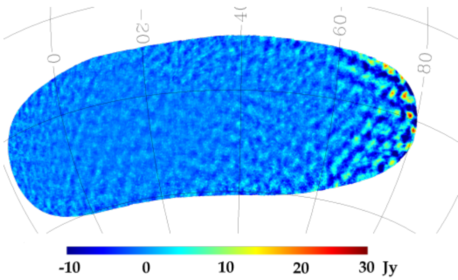
<u>Publication details:</u>

K. W. Bannister, T. Murphy, B. M. Gaensler, J. E. Reynolds in ApJ 757 "*Limits on Prompt, Dispersed Radio Pulses from Gamma-Ray Bursts*"

New algorithm efficiently detects radio sources in MWA 32T data

With the world awaiting construction of the ultimate radio telescope, the Square Kilometre Array (SKA), the concept of interferometry has found unprecedented attention. In short, we can achieve a similar sensitivity, resolution, and collecting area as that of a much larger radio telescope by simultaneously collecting data from an array of smaller instruments, defined by the observing frequency and maximum distance between the individual instruments. Things become tricky, however, when the data streams from these individual telescopes have to be combined, compared, and corrected for directionality and polarisation to reliably detect radio sources in the Universe.

In a publication by an international team, led by the University of Washington with a number of our CAASTRO researchers on board, a neat new technique is presented that deals with these data streams in a very efficient way (The Astrophysical Journal 759). Speed and precision are two key factors to trade off in analysing the immense amounts of data generated by next-generation radio telescopes, such as the Murchison Widefield Array (MWA) in Western Australia. For their paper, Sullivan et al. only needed five minutes of observing time with the 32-antenna MWA prototype to collect enough data to test their new algorithm to the fullest extent. Despite being called ‘visibilities’, not much is visible in the noisy raw data that come straight from the MWA. A whole lot of complex maths is required to interpret foreground radio interference, produce images and identify false objects, for which a number of smart algorithms have been developed over



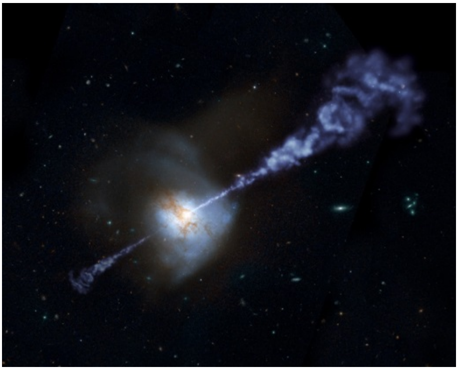
the years. The new algorithm described here – called Fast Holographic Deconvolution – creates holographic maps that contain directionality and polarisation information for each individual antenna. Sullivan et al. found that the algorithm performs very well, reducing the processing time of huge data sets to as little as 1% compared to previous tools. And in addition to being fast, the algorithm was also successful in detecting 2342 candidate objects for radio sources in the data.

Publication details:

I. Sullivan, M. Morales, B. Hazelton, W. Arcus, D. Barnes, G. Bernardi, F. Briggs, J. D. Bowman, J. Bunton, R. Cappallo, B. Corey, A. Deshpande, L. deSouza, D. Emrich, B. M. Gaensler, R. Goeke, L. Greenhill, D. Herne, J. Hewitt, M. Johnston-Hollitt, D. Kaplan, J. Kasper, B. Kincaid, R. Koenig, E. Kratzenberg, C. Lonsdale, M. Lynch, R. McWhirter, D. Mitchell, E. Morgan, D. Oberoi, S. Ord, J. Pathikulangara, T. Prabu, R. Remillard, A. Rogers, A. Roshi, J. Salah, R. Sault, U. Shankar, K. Srivani, J. Stevens, R. Subrahmanyan, S. Tingay, R. Wayth, M. Waterson, R. Webster, A. Whitney, A. Williams, C. Williams, S. Wyithe in ApJ 759 "*Fast Holographic Deconvolution: a new Technique for Precision Radio Interferometry*"

The hydrogen gas in high redshift galaxies is fully ionised

In their 2008 publication, Stephen Curran and colleagues discussed their study of far-away galaxies that are devoid of cool hydrogen gas – the fuel for star formation. Since observing distant galaxies also means looking far back in time (in this case, 11.5 billion years, i.e. just 2 billion years after the Big Bang), a dearth of hydrogen is unexpected as these galaxies should be in an active star-forming state. Discussing this surprising result, they concluded that the gas could be superheated and ionised and that follow-up observations with a much more sensitive next generation radio telescope, such as the Square Kilometre Array (SKA), will be required.



Meanwhile, as construction of the SKA precursor instruments in Western Australia and South Africa progresses, Curran – a CAASTRO Research Fellow at the University of Sydney – and his collaborator Matthew Whiting (CSIRO Astronomy & Space Science) have analysed their data carefully to find a physically plausible model to explain their observations. In their new publication (The Astrophysical Journal 759), they present their '21-cm effect' that is a cut-off in the detection rate of cool hydrogen gas at a single critical luminosity in the ultraviolet wavelength range. Having determined the ionising photon rate to be just under 3 x 10^{56} photons per second, the UV luminosity proves sufficient to ionise all gas in a galaxy, and the model also accounts for a balance in the particle dynamics as photon density decreases exponentially with distance from the galaxy nucleus, the ionising source. Their model therefore re-creates the observed cut-off in detections, naturally explains how a large-scale distribution of atomic gas in large spiral galaxies, such as our own Milky Way, can be completely ionised, and rules out that previous observations were corrupted by effects of viewing angle or, indeed, telescope sensitivity.

So while we are waiting for the SKA to come online, Stephen has shown that diligent number-crunching and thorough analysis can still teach us a lot about the distant Universe!

Publication details:

S.J. Curran & M.T. Whiting in ApJ 759 "*Complete Ionisation of the Neutral Gas: why there are so few Detections of 21-cm Hydrogen in High Redshift Radio Galaxies and Quasars*"

The 128-tile MWA is able to detect the Epoch of Reionisation

The Murchison Widefield Array (MWA) is the low-frequency SKA precursor being built at the radio-quiet Murchison Radio-astronomy Observatory (MRO) in Western Australia and will be sensitive enough to pick up faint radio signals from the very early Universe. This era shortly after the Big Bang when cool atomic hydrogen gas was heated and ionised by the first light-emitting objects in the Universe, called the Epoch of Reionisation (EoR), is still poorly understood and as such is one of the MWA's main science goals. A central core of 112 tiles (covering an area of approximately 1.5 square kilometres) yields an impressive field of view of approximately 40°, with short baselines and good conditions for calibrating and adjusting the instrument to overcome contaminating foreground signals from our own galaxy and distant galaxies.

A new publication by the MWA consortium, with lead author Adam Beardsley, a PhD student from the University of Washington, and a number of CAASTRO co-authors (Monthly Notices of the Royal Astronomical Society – Letters 429), presents an estimate of the sensitivity of the MWA to the faint signals from the EoR. The researchers based their calculations on a neutral intergalactic medium and the standard model of cosmology (λ Cold Dark Matter), assuming an isotropic (i.e. uniform in all directions) distribution of matter in the Universe.

Taking a couple of restrictions on the MWA measurements into account, the team can characterise the "EoR window" in the power spectrum sensitivity. Depending on the amount of observation time obtained with the MWA (and assuming that the instrument stability is sufficiently good), the MWA is expected to be able to detect the EoR signal at a Signal-to-Noise level of up to 14.

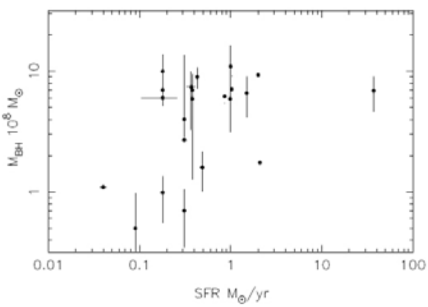
Publication details:

A. P. Beardsley, B. J. Hazelton, M. F. Morales, W. Arcus, D. Barnes, G. Bernardi, J. D. Bowman, F. H. Briggs, J. D. Bunton, R. J. Cappallo, B. E. Corey, A. Deshpande, L. deSouza, D. Emrich, B. M. Gaensler, R. Goeke, L. J. Greenhill, D. Herne, J. N. Hewitt, M. Johnston-Hollitt, D. L. Kaplan, J. C. Kasper, B. B. Kincaid, R. Koenig, E. Kratzenberg, C. J. Lonsdale, M. J. Lynch, S. R. McWhirter, D. A. Mitchell, E. Morgan, D. Oberoi, S. M. Ord, J. Pathikulangara, T. Prabu, R. A. Remillard, A. E. E. Rogers, A. Roshi, J. E. Salah, R. J. Sault, N. Udaya Shankar, K. S. Srivani, J. Stevens, R. Subrahmanyan, S. J. Tingay, R. B. Wayth, M. Waterson, R. L. Webster, A. R. Whitney, A. Williams, C. L. Williams, J. S. B. Wyithe in MNRAS Letters 429 "*The EoR Sensitivity of the 128 Antenna Murchison Widefield Array*"

New program to study nuclear gas in nearby radio-loud galaxies

Our understanding of the physical mechanisms behind the formation of stars and galaxies has greatly improved over the last couple of decades but new technology in hardware and software will keep driving these endeavours further still. These new technologies will be needed to, for instance, verify whether all massive galaxies are sources of radio emission, fuelled by a Black Hole located in the galactic centre.

As the first stage of a new research project, a paper by a Swinburne University based CAASTRO member, Professor Jeremy Mould, and his Australian and overseas colleagues describes their analysis of nuclear activity in galaxies close to our own (The Astrophysical Journal – Supplement Series 203). As one of the first objectives of the project, the research team looked at a potential correlation between the growth of the central Black Hole and the rate of star formation in the galaxy. They conducted their survey of infrared emission lines using spectrographs on the Palomar and Kitt Peak National Observatories in the US, targeting suitably close and radio active galaxies (previously catalogued in a 2011 publication).



For a fraction of these galaxies, they found nuclear spectra and infrared emission line nuclei with six times the average radio emission at a given stellar mass. This means that the Black Holes in these galaxies are currently growing by accreting matter from its surrounding gas disk. The researchers further calculated a star formation rate of 0.4 Solar Masses per year.

Publication details:

J. Mould, T. Reynolds, T. Readhead, D. Floyd, B. Jannuzi, G. Cotter, L. Ferrarese, K. Matthews, D. Atlee, M. Brown in ApJS 203 “*Infrared spectroscopy of nearby radio active elliptical galaxies*”

Faint objects are also devoid of neutral hydrogen gas

Previously, Sydney based CAASTRO Research Fellow Dr Stephen Curran discussed far-away radio galaxies and quasars that seem not to contain any cool neutral hydrogen gas – the fuel for star formation – (2008 publication in MNRAS) and presented a physically plausible model to explain these observations (2012 publication in ApJ). He and his colleagues concluded that the gas in these distant galaxies was completely ionised due to strong ultraviolet radiation, such that there was no detection of cool hydrogen above a critical ultra-violet luminosity. However, a selection bias towards optically bright objects in these studies could mean that there remains the possibility of a population of fainter objects where hydrogen is not ionised.

In a new publication (Monthly Notices of the Royal Astronomical Society 428), Dr Curran, together with CAASTRO co-author Professor Elaine Sadler, Dr Matthew Whiting (CSIRO), and Dr Carl Bignell (National Radio Astronomy Observatory, USA), set out to look closely at optically faint, radio-loud objects in which, according to the above logic, cool neutral hydrogen gas should be present and detectable.

Using data from the Green Bank Telescope in the USA and the Westerbork Synthesis Radio Telescope in the Netherlands, the research team analysed 11 radio sources of which eight yielded analysable data. Despite expecting at least three detections of the neutral hydrogen signal, there were none – which might be due to extended radio emission of the selected sources that reduces coverage of the absorbing gas and therefore makes the survey less sensitive.

Discussing further reasons for the non-detections, the authors consider the fact that galaxies in the distant, early Universe are smaller and their hydrogen more likely to be fully ionised. To study even fainter objects, a more sensitive radio telescope like the Square Kilometre Array (SKA) will be required.

Publication details:

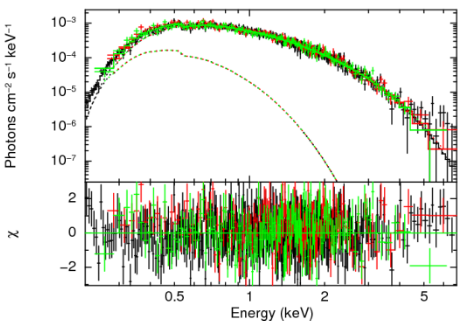
S. J. Curran, M. T. Whiting, E. M. Sadler, C. Bignell in MNRAS 428 "*A survey for the missing hydrogen in high redshift radio sources*"

Milky Way or nearby Galaxy home to unusual variable X-ray source

A very unusual stellar object has been found that is either located in our own Galaxy or in M31, the Andromeda Galaxy, the closest normal galaxy to us. Undetected in observations with various X-ray telescopes for many years, the 2008 European Space Agency's X-ray Multi-Mirror Mission (XMM-Newton) survey of M31 suddenly picked it up as a bright X-ray source. In a 2011 Astronomy & Astrophysics paper, the object was identified as a probable black hole low-mass X-ray binary.

A publication in The Astrophysical Journal, with lead author Joseph Callingham from the University of Sydney and two CAASTRO co-authors, presents a detailed re-analysis of the object's spectral and timing properties that might point towards a rare class of Galactic magnetars. Most intriguingly, the source remained elusive in follow-up observations by the research team, using the Swift X-ray Telescope in 2011, and in archival data at different wavelengths (ultra-violet, optical, near-infrared, and radio at several frequencies).

The X-ray variability and lack of an identifiable counterpart place strong constraints on the nature of this source, ruling out emission-stable objects such as cooling neutron stars. The team re-analysed the 2008 XMM-Newton data and tested a number of different models to best fit the spectrum. They found that while a the X-ray spectrum is similar in shape to that typically seen from black hole binaries, other properties were very unusual for a black hole binary, namely a very low accretion disc temperature and a non-variable Compton component. In addition, the location of the source in the periphery of M31 is hard to explain, as such binary systems are usually located in or



near globular clusters or star-forming regions. Investigating, therefore, whether the source could be something else than a black hole binary in M31, an equally good fit was achieved assuming the source is a magnetar – which would also account for the observed flux ratio variability and the lack of counterparts – but would suggest that the source belongs to our Milky Way Galaxy. Yet again, the source would be located in a rather unusual place – a fair way out of the galactic plane.

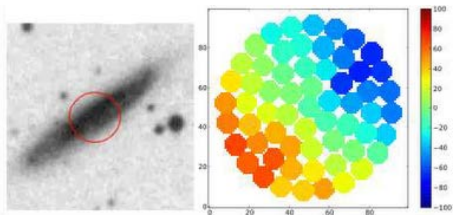
Callingham et al. also discuss the origin of the object and conclude that – assuming it is a magnetar –it was either born in a supernova from a massive progenitor star in the Galactic plane, travelled out and decreased in magnetic field strength, or that it is a run-away progenitor star that separated from a binary system. To clarify, however, whether the object is a magnetar or a black hole X-ray binary after all, we will need to detect spectral state transitions (typical of black hole binaries) or pulsations (typical of magnetars).

Publication details:

J. R. Callingham, S. A. Farrell, B. M. Gaensler, G. F. Lewis, M. J. Middleton in ApJ 757 "*The X-ray Transient 2XMMi J003833.3+402133: A Candidate Magnetar at High Galactic Latitude*"

SAMI finds windy galaxy using spatially resolved optical spectra

SAMI, the Sydney-AAO Multi-object Integral Field Spectrograph, is a new instrument mounted on the Anglo-Australian Telescope and the first spectrograph to use hexabundles. A hexabundle is the extension of a technology that takes the light from a large optical telescope at a particular point in the focal plane and directs it down an optical fibre to a detector, such as a spectrograph. Instead of single optical fibres, hexabundles use multiple fibres fused together to cover a larger area than possible with a single fibre, allowing the spectra of extended objects to be studied efficiently and in detail. Each of SAMI's 13 hexabundles contains 61 optical fibres of 105 µm diameter, arranged in a circular pattern and lightly fused to give a field of view of 14".9 on sky (sampling 1".6 per fibre).



The first SAMI science commissioning run in mid 2011 targeted a single field on the sky, selected from the 6dF Galaxy Survey. One particular object on which a hexabundle was placed (ESO 185-G031 at a redshift of z=0.016) attracted the attention of Dr Lisa Fogarty and her colleagues in Sydney and the USA (including CAASTRO co-authors) because of interesting kinematic characteristics and emission lines that were immediately seen in the spatially resolved spectra from the hexabundle. Their analysis has now been published in The Astrophysical Journal 761.

Measuring seven optical gas emission lines, the team was able to construct spatially resolved maps of common line ratios that give an indication of the ionisation mechanisms at work. They found that while the disk of the galaxy was dominated by ionisation due to star formation (at a rate of 1.7 solar masses per year), the ionisation source of gas further away from the disk was likely shock excitation. Analysing the gas kinematics of ESO 185-G031, Fogarty et al. could further support their hypothesis of two different ionisation mechanisms and conclude that they have identified a gas outflow that was not rotating with the disk – i.e. a galactic wind. The detection of such phenomena can help our understanding of galaxy evolution.

SAMI and its hexabundles have also already proven very effective in characterising the morphology of galaxies, especially if these do not exhibit symmetry.

<u>Publication details:</u>

L. M. R. Fogarty, J. Bland-Hawthorn, S. M. Croom, A. W. Green, J. J. Bryant, J. S. Lawrence, S. Richards, J. T. Allen, A. E. Bauer, M. N. Birchall, S. Brough, M. Colless, S. C. Ellis, T. Farrell, M. Goodwin, R. Heald, A. M. Hopkins, A. Horton, D. H. Jones, S. Lee, G. Lewis, A. R. Lopez-Sanchez, S. Miziarski, H. Trowland, S. G. Leon-Saval, S.-S. Min, C. Trinh, G. Cecil, S. Veilleux, K. Kreimeyer in ApJ 761 “*First Science with SAMI: a Serendipitously Discovered Galactic Wind in ESO 185-G031*”

First microquasar outside of our Galaxy found

A paper by Matthew Middleton (previously at the University of Durham, now University of Amsterdam) and his large international team of co-authors has been published in Nature, bringing together X-ray and radio observations of a source in our neighbouring galaxy, M31 or Andromeda. The authors were able to characterise this source as a rare highly compact, accreting, ultraluminous Black Hole. The European Space Agency's XMM-Newton satellite first detected XMMU J004243.6+412519 in early 2012 and recorded a peak luminosity of 1.26 x 10^{39} erg per second, from which the researchers could calculate a mass accretion rate close to the theoretical maximum (Eddington limit).

Based on follow-up observations in X-ray and radio, the team found that the source's emissions were variable, indicating that they were not nebular in origin but rather due to a highly compact region that emits relativistic jets. One of the authors, CAASTRO Associate Investigator Jean-Pierre Macquart (Curtin University), was involved in the scintillation analysis in this study.

Thanks to having collected both X-ray and radio data, the team can be confident that their discovery is a Black Hole with an estimated stellar mass of approximately ten times that of our Sun. It appears to be dominated by its accretion disk that is drawing from a lower-mass companion star. Only four such objects have been previously found in our Milky Way, and XMMU J004243.6+412519 is the first of these 'microquasars' that is located outside of our Galaxy.

Publication details:

M. J. Middleton, J. C. A. Miller-Jones, S. Markoff, R. Fender, M. Henze, N. Hurley-Walker, A. M. M. Scaife, T. P. Roberts, D. Walton, J. Carpenter, J.-P. Macquart, G. C. Bower, M. Gurwell, W. Pietsch, F. Haberl, J. Harris, M. Daniel, M. Miah,

C. Done, J. Morgan, H. Dickinson, P. Charles, V. Burwitz, M. Della Valle, M. Freyberg, J. Greiner, M. Hernanz, D. H. Hartmann, D. Hatzidimitriou, A. Riffeser, G. Sala, S. Seitz, P. Reig, A. Rau, M. Orio, D. Titterington, K. Grainge in Nature 493 "*Bright radio emission from an ultraluminous stellar-mass microquasar in M31*"

Australian low-frequency precursor ready for SKA Phase 1 science

The Murchison Widefield Array (MWA) is an interferometric radio telescope operating at low radio frequencies (80-300 MHz), composed of 128 aperture arrays ('tiles') and located at the Murchison Radio-astronomy Observatory (MRO) in Western Australia. The instrument qualified as the official SKA-low precursor because it serves as a technology demonstrator at the chosen Australian site of the Square Kilometre Array (SKA) where levels of human-made radio frequency interference are extremely low. Just as the other two SKA precursors, CSIRO's Australian SKA Pathfinder (ASKAP) and the South African MeerKAT, the MWA has undergone a prototype test phase (32 tiles) which has recently been decommissioned and re-built as the full 128-tile array. Of the three SKA precursors, the MWA will be the first to commence operations, in 2013. Its modular layout, with a high tile density in a core region and spread-out tiles over several kilometres, was driven by the four main science goals for which the instrument was optimised. These goals are detection of the Epoch of Reionisation in the early Universe, galactic and extra-galactic processes, transient radio sources and solar science.

In their paper (Publications of the Astronomical Society of Australia 30), MWA Director and CAASTRO Chief Investigator at Curtin University Professor Steven Tingay and the international MWA consortium provide a full description of the telescope, including its final system architecture and sub-systems, signal processing and data handling strategies.

Data collection with the MWA starts with small, low-noise amplifying dual-polarisation dipole antennas, 16 to a tile, mounted on a 5m x 5m mesh ground plane. The radio frequency signals of all dipoles are fed into an analogue beamformer, where signal delays provide directionality and make up for the lack of movable parts to point the telescope in 256 possible directions. Filtering and digital conversion of the analogue signals takes place in 16 receiver elements, each processing data from eight tiles. The digital data are transmitted via fibre optic links to a CSIRO-owned Central Processing Facility on-site where data are processed, calibrated and imaged, prior to being transmitted to the Pawsey High Performance Computing Centre for SKA Science in Perth, a dedicated supercomputing facility currently under construction.

All components have been designed and laid out to be flexible, modifiable and upgradable in the future – a valuable lesson learnt from the prototype test phase. Systems also had to be constructed such that they would not introduce any radio frequency interference into the pristine environment and could operate in the open field. Users of the MWA telescope, however, will be able to stay in the comfort of their research institute by using a web-based interface for remote operations.

Publication details:

S. J. Tingay, R. Goeke, J. D. Bowman, D. Emrich, S. M. Ord, D. A. Mitchell, M. F. Morales, T. Booler, B. Crosse, D. Pallot, A. Wicenec, W. Arcus, D. Barnes, G. Bernardi, F. Briggs, S. Burns, J. D. Bunton, R. J. Cappallo, T. Colegate, B. E. Corey, A. Deshpande, L. deSouza, B. M. Gaensler, L. J. Greenhill, J. Hall, B. J. Hazelton, D. Herne, J. N. Hewitt, M. Johnston-Hollitt, D. L. Kaplan, J. C. Kasper, B. B. Kincaid, R. Koenig, E. Kratzenberg, C. J. Lonsdale, M. J. Lynch, B. McKinley, S. R. McWhirter, E. Morgan, D. Oberoi, J. Pathikulangara, T. Prabu, R. A. Remillard, A. E. E. Rogers, A. Roshi, J. E. Salah, R. J. Sault, N. Udaya-Shankar, F. Schlagenhaufer, K. S. Srivani, J. Stevens, R. Subrahmanyan, S. Tremblay, R. B. Wayth, M. Waterson, R. L. Webster, A. R. Whitney, A. Williams, C. L. Williams, J. S. B. Wyithe in PASA 30 "*The Murchison Widefield Array: the Square Kilometre Array Precursor at low radio frequencies*"

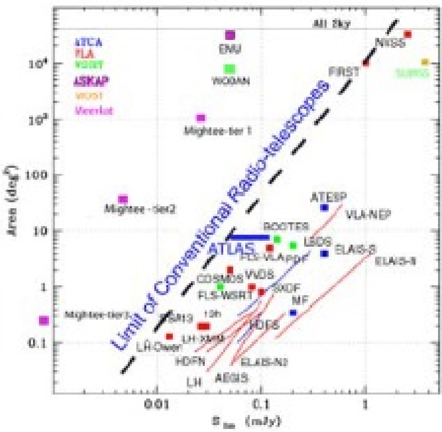
The SPARCS Working Group streamlines efforts towards SKA surveys

In a time when precursor instruments to the Square Kilometre Array (SKA) from all over the world are coming online and start generating data, the recently founded SKA Pathfinder Radio Continuum Survey Working Group will make sure that the radio-astronomical community achieves good coordination and communication in tackling scientific and technological challenges.

In a review paper in the Publications of the Astronomical Society Australia, CAASTRO Partner Investigator Ray Norris (CSIRO) and his co-authors describe the current state-of-play of these new SKA pathfinders with the aim to facilitate sharing resources and expertise and thereby maximise the science return.

The paper provides a baseline of knowledge for the teams behind these next-generation telescopes: Europe-based APERTIF, LOFAR, e-EVN and eMERLIN, Meerkat in South Africa, VLA in the US, and of course ASKAP and MWA in Western Australia – each planning to conduct a radio continuum survey with the primary science objective of understanding the formation and evolution of galaxies over cosmic time and the cosmological parameters and large-scale structures that drive it.

These highly sensitive new instruments with their large dynamic ranges allow surveys to go beyond the traditional limits of radio astronomy which means that results will be less similar to 'old' radio signals than to data obtained at different wavelengths – yet another incentive for strong



collaborative efforts within the astronomical community. As teams are working towards sophisticated hardware and software solutions to address calibration, imaging, classification etc, highlighting commonalities and parallels between individual systems can save significant amounts of time and money and can fast-track progress towards achieving our science goals.

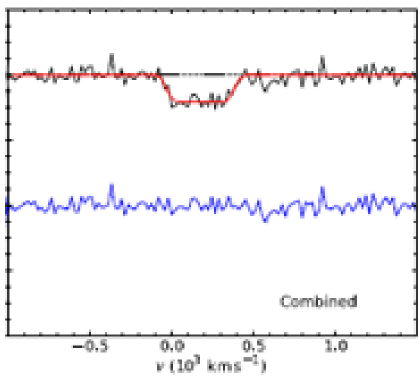
Publication details:

R. P. Norris, J. Afonso, D. Bacon, R. Beck, M. Bell, R. J. Beswick, P. Best, S. Bhatnagar, A. Bonafede, G. Brunetti, T. Budavari, R. Cassano, J. J. Condo, C. Cress, A. Dabbech, I. Feain, R. Fender, C. Ferrari, B. M. Gaensler, G. Giovannini, M. Haverkorn, G. Heald, K. van der Heyden, A. M. Hopkins, M. Jarvis, M. Johnston-Hollitt, R. Kothes, H. van Langevelde, J. Lazio, M. Y. Mao, A. Martınez-Sansigre, D. Mary, K. McAlpine, E. Middelberg, E. Murphy, P. Padovani, Z. Paragi, I. Prandoni, A. Raccanelli, E. Rigby, I. G. Roseboom, H. Rottgering, J. Sabater, M. Salvato, A. M. M. Scaife, R. Schilizzi, N. Seymour, D. J. B. Smith, G. Umana, G.-B. Zhao, P.-C. Zinn in PASA "*Radio Continuum Surveys with Square Kilometre Array Pathfinders*"

Broadest ever absorption line shows cold HI speeding towards AGN

Observations of the compact radio source PMN J2054-4242 with the 6-dish Australian Telescope Compact Array (ATCA) and its Broadband Backend (CABB) have now revealed the broadest and weakest absorption line of cold neutral hydrogen gas at 21cm yet detected. Observations of such lines have been rare, but this might change now with a new Bayesian spectral-line finding and fitting technique that is a promising tool for upcoming large-scale blind surveys on next generation radio telescopes such as ASKAP and the SKA.

In their new publication (Monthly Notices of the Royal Astronomical Society 430), the team of four Sydney-based CAASTRO researchers present their extended observations and analyses – building on a previous paper (MNRAS 2012) – and confirm the existence of this broad HI absorption line, using their new technique.



From the spectral-line and optical spectroscopic redshifts, the researchers also concluded that the detection relates to cold gas either rotating or infalling towards the central radio source (or Active Galactic Nucleus, AGN) at high speed, either in one single gas cloud or in a blended sequence of clouds. High velocity gas flows can provide insights into feedback between the radio source and star formation in the host galaxy.

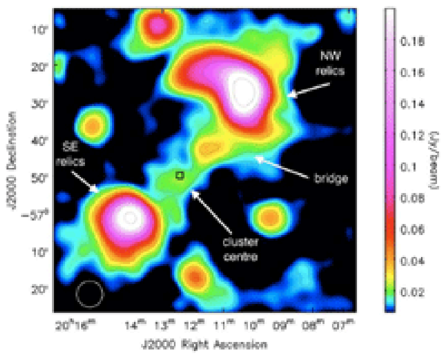
<u>Publication details:</u>

J. R. Allison, S. J. Curran, E. M. Sadler, S. N. Reeves in MNRAS 430 "*Broad, weak 21 cm absorption in an early type galaxy: spectral-line finding and parameterisation for future surveys*"

Shockwaves of galaxy cluster merger seen as bridge in radio data

As part of S-PASS (S-band Polarization All Sky Survey), a single-dish survey of the total intensity and polarised continuum emission of the entire southern sky, observations at 2.3 GHz with the Parkes Radio Telescope have now revealed a ‘bridge’ of unpolarised synchrotron emission (stretching one third of a degree on the sky) between the centre of cluster Abell 3667 and its outlying relic regions. This is the first significant detection of such a connecting structure associated with both a cluster relic and X-ray emission from the cluster centre.

In their paper, the team around CSIRO lead author Ettore Carretti, including our CAASTRO Directors Bryan Gaensler and Lister Staveley-Smith, carefully stripped their single-dish data from confounding signals, using nine hours of observations with the Australia Telescope Compact Array at the S-PASS frequency for compact source subtraction. The detection of the two radio relics were confirmed by previous data sets from the Molonglo Observatory Synthesis Telescope (MOST).



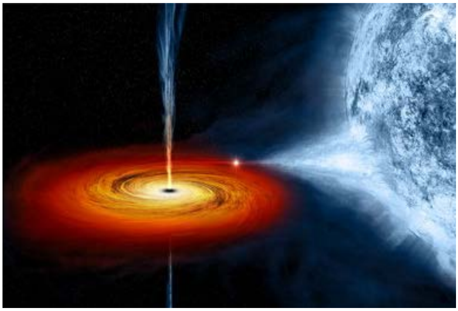
The researchers interpret their data as an indication that Abell 3667 shows the aftermaths of a collision between two merging galaxy clusters that generated outgoing shock waves. The observed synchrotron emission ‘bridge’ is thought to be the post-shock turbulence trailing the shock.

Publication details:

E. Carretti, S. Brown, L. Staveley-Smith, J. M. Malarecki, G. Bernardi, B. M. Gaensler, M. Haverkorn, M. J. Kesteven, S. Poppi in MNRAS 430 *“Detection of a radio bridge in Abell 3667”*

Simulations suggest importance of X-rays in cosmic reionisation

In their 2009 paper in MNRAS, CAASTRO Associate Investigator Chris Power and his European colleagues started exploring the way in which high-mass X-ray binaries in primordial globular clusters could boost the ionising power of these clusters. The team now has a new publication that examines the role high-mass X-ray binary systems could play in ionising the neutral gas that dominated the early Universe.



The 2009 simulation was extended to a Monte Carlo model that assumes both black-body and power-law components. The model starts with a stellar population from a single instantaneous burst of star formation and evolves over 250 million years, during which time massive stars form and turn into high-mass X-ray binaries. All limits of stellar mass and formation rates were based on recent published data. The results of the simulations show that high-mass X-ray binaries dominate the ionising power after 20 million years and continue to peak up to 40 million years, after which no more massive stars exist to form such systems and the ionising power declines sharply. In contrast to the massive stars, the binaries are much longer lasting ionising sources, up to 100 million years.

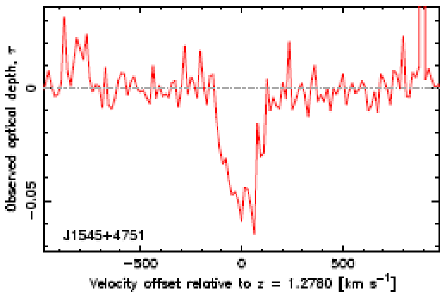
The calculation of how much high-mass X-ray binaries contribute to the present-day X-ray background critically depends on the underlying star formation rate. The model used here determined a contribution of 5×10^{-16} erg s^{-1} cm^{-2} deg^{-2} which is factor 100-1000 smaller than the observed limit.

Publication details:

C. Power, G. F. James, C. Combet, G. Wynn in ApJ 28 "*Feedback from high-mass X-ray binaries on the high redshift intergalactic medium: model spectra*"

Elusive evidence of neutral hydrogen in the distant Universe

Continuing their studies of cool neutral hydrogen gas – the fuel for star formation – in the distant Universe, the research team around CAASTRO researcher Stephen Curran has succeeded in detecting the signal of HI absorption at the third highest redshift reported to date, at a look-back time of approximately nine billion years. Their current survey specifically targeted very faint sources that lie below their previously determined cut-off luminosity above which all hydrogen in a galaxy is ionised.



The team pre-identified ten candidate sources using Parkes radio source catalogues and observed them at 610 MHz with the 30-antenna array Giant Metrewave Radio Telescope in India in January 2012. Of these galaxies, four had to be excluded due to poor data quality. Taking other factors into account that render data unreliable, only three sources were deemed worthy of full analysis.

One of the three sources (J1545+4751) exhibited the flattest spectral energy distribution and yielded a detection of the 21-cm absorption signal. Observations with the Very Long Baseline Array had previously confirmed this radio source as very compact. The radio power for this source was found to be lower than for the other candidates but higher than in observations at higher redshift where HI absorption is yet to be observed.

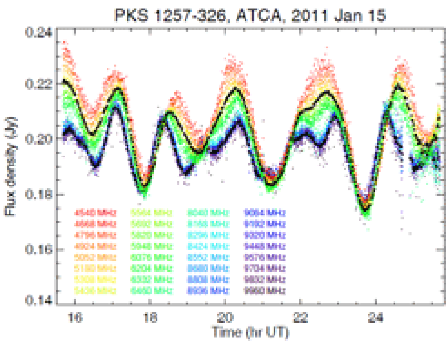
<u>Publication details:</u>

S. J. Curran, M. T. Whiting, A. Tanna, E. M. Sadler, M. B. Pracy, R. Athreya in MNRAS 429 "*A survey for HI in the distant Universe: the detection of associated 21-cm absorption at z = 1.28*"

Precise calculations of core shift and pressure gradient of AGNs

While the examination of the bright and compact cores of Active Galactic Nuclei (AGNs) by Very Long Baseline Interferometry (VLBI) is limited, due to frequency dependent variations in density of the core and emitted jets, a new technique now offers a frequency-independent approach and unprecedented precision. CAASTRO Associate Investigator Jean-Pierre Macquart and his colleagues used observations with the Australia Telescope Compact Array to test their new approach and calculated a core shift for source ‘PKS 1257-326’ an order of magnitude smaller than respective VLBI measurements.

Their interstellar scintillation analysis was based on frequency-dependent flux density light curves and delays in the arrival times of annually modulated variations obtained from the source. Cross-correlating and fitting the light curves yielded delays of up to 600 seconds that could be related to the structure of its jets. At the lowest observing frequency (4540 MHz), the physical size of the core shift was calculated to be 0.16 parsecs, and 0.10 parsecs at the highest frequency of 9960 MHz.



The team further analysed the morphology of the jets and found that their opening angle increased with distance from the core (‘flaring’) and that their remarkable stability might be due to the high pressure gradient, contained by hydrostatic equilibrium with the surrounding medium.

Publication details:

J.-P. Macquart, L. E. H. Godfrey, H. E. Bignall, J. A. Hodgson in ApJ 765 "*The microarcsecond structure of an AGN jet via interstellar scintillation*"