ASKAP EMU
Evolutionary Map of the Universe

What is EMU ?

EMU is a radio sky survey project which will use the new ASKAP telescope to make a deep (10μJy rms) radio continuum survey covering the entire Southern Sky as far North as +30°. It can be characterized as a "Southern NVSS", except that it will have about 40 times the sensitivity, six times the resolution and will detect 70 million galaxies. As a result, it will be able to probe star forming galaxies up to z=1, AGNs to the edge of the Universe, and will undoubtedly uncover new classes of object.

Credit:
Top, Alex Cherney, http://www.terrastro.com/
Bottom, CSIRO

Australian SKA Pathfinder Newsletter issue 13 November 2017

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From the Editor

Dear EMU team members,

Welcome to the 13th issue of the EMU Newsletter. This Newsletter provides an update on the status of the Australian Square Kilometre Array Pathfinder (ASKAP) to the consortium and other interested people. It has been a busy and exciting few months for the members of the EMU team and the ASKAP project. I thank the consortium members and project leaders who have contributed articles for publications as well as this Newsletter.

I would encourage you to continue to send in submissions for future issues. Small snippets or images are most welcome as are profiles of team members. This newsletter is only as useful as the contributions received from team members. It serves as both a record of the development of the project and a means to promote ideas and issues that can then be followed up through discussion on the project Wiki http://www.askap.pbworks.com.

If you have any suggestions as to what you would like to see included in the newsletter please let me know.

Submissions for the next issue are due: 15th April 2018. Email reminders will be sent closer to the date.
Please note that Kate Chow (Editor for earlier version of EMU Newsletters) is on maternity leave, we wish her a good family time!

I hope you enjoy this edition of the EMU Newsletter.

Dr. Mamta Pandey-Pommier
Editor
CRAL- l'Observatoire de Lyon, France

Figure 1: ASKAP array (credit CSIRO).

Editorial from the Project Leader

Dear EMU member

Welcome to the 13th EMU newsletter. A great deal has happened since the last newsletter, as ASKAP ramps up towards early science. This week marked a milestone as the last phased array feed (PAF) was installed on ASKAP, so we now have 36 antennas fully equipped with state-of-art PAF receivers. As I write this, ASKAP is now routinely observing with 16 antennas at a bandwidth of 240 MHz, and we are starting to obtain continuum images that go significantly deeper than existing radio images. Fig 1 shows one such image, which is deeper than any existing radio image of the Small Magellanic Cloud. However, the noise level is still somewhat higher than expected, suggesting that further development is needed on beam-forming, calibration, and flagging of radio frequency interference (RFI).

Because we do not yet understand the calibration and RFI flagging issues which are preventing us from reaching the expected noise levels, we have decided to defer the start of "EMU early science", and instead we are in the "Science Verification Phase". In practice, this means that our choice of observing is primarily determined by the need to test and develop observing and processing techniques, rather than being primarily science-driven. However, as the Figures show, we are still generating plenty of science!

As ASKAP construction and commissioning ramps up, we have seen a trickle of "science verification" data which is now becoming a torrent. Of course, we still have far more to do to hone the data processing and calibration techniques for ASKAP, and so these data are not yet approaching the final quality that we expect from ASKAP, and yet, even at this early stage, the data are already giving us fresh insights that were not previously available. The ASKAP images of the important and well studied GAMA, SPT-XXL, and Chandra Deep Field South fields are already overtaking the best data previously available, and extend our knowledge of the spectral behaviour of radio sources to frequencies not previously observed at this sensitivity.

A few weeks ago we held the first "EMU busy week", where in collaboration with ASKAP projects WALLABY and POSSUM, we encouraged EMU users to experiment with ASKAP data. Participants spent the week learning how to access and validate the data, and how to process it on the high-performance computers at the Pawsey Centre. Nobody said it would be easy, and yet some participants managed to get high-quality images out of the process. At least one paper (on the star formation rates in the GAMA field) is already in preparation, and we hope more will soon be on the way. Equally important were the lessons learned, which will be addressed in subsequent iterations of our software and our processes.

The EMU busy week was skillfully managed by Jordan Collier, with the enthusiastic help of the ACES team led by Aidan Hotan. Thanks are due to all these people, and to our colleagues in WALLABY and POSSUM, and to the participants who provided such valuable feedback. We are all on a learning curve, and shared experiences like the busy week will help us get up there even faster.

We expect to transition to "Early Science" early in 2018, and will then start to observe the EMU "Early Science fields", which are primarily science-driven, but will also be used to hone our observation and processing techniques. Individual Early Science Teams will be primarily responsible for processing their data, with help from the ACES team and from CSIRO experts within EMU. So initially, these Early Science Teams should plan to nominate a member of their team who will become expert in ASKAP data processing, and should attend one of the EMU

"Busy Weeks" held at CASS so that they become familiar with the required techniques. Later, some more automated processing may become possible, but initially the first Early Science observing allocations will be made to those teams who are ready to process their data.

Since EMU and the other science surveys were first proposed in 2009, we now know far more about the technical performance of ASKAP, and the science has also changed. For example, in 2009, the field of Fast Radio Bursts had barely started, but is now potentially an important science driver for ASKAP. Even within EMU, our science priorities have changed. For example, in 2009 we knew that cosmology was potentially an important science goal for EMU, but we didn't appreciate the enormous impact that EMU is expected to make on cosmology.

Because of such changes, in mid-2018 there will be a very important review of all ASKAP survey science projects, and all ASKAP survey science teams will be invited to submit revised project proposals. EMU is in very good shape, and we welcome this review, which

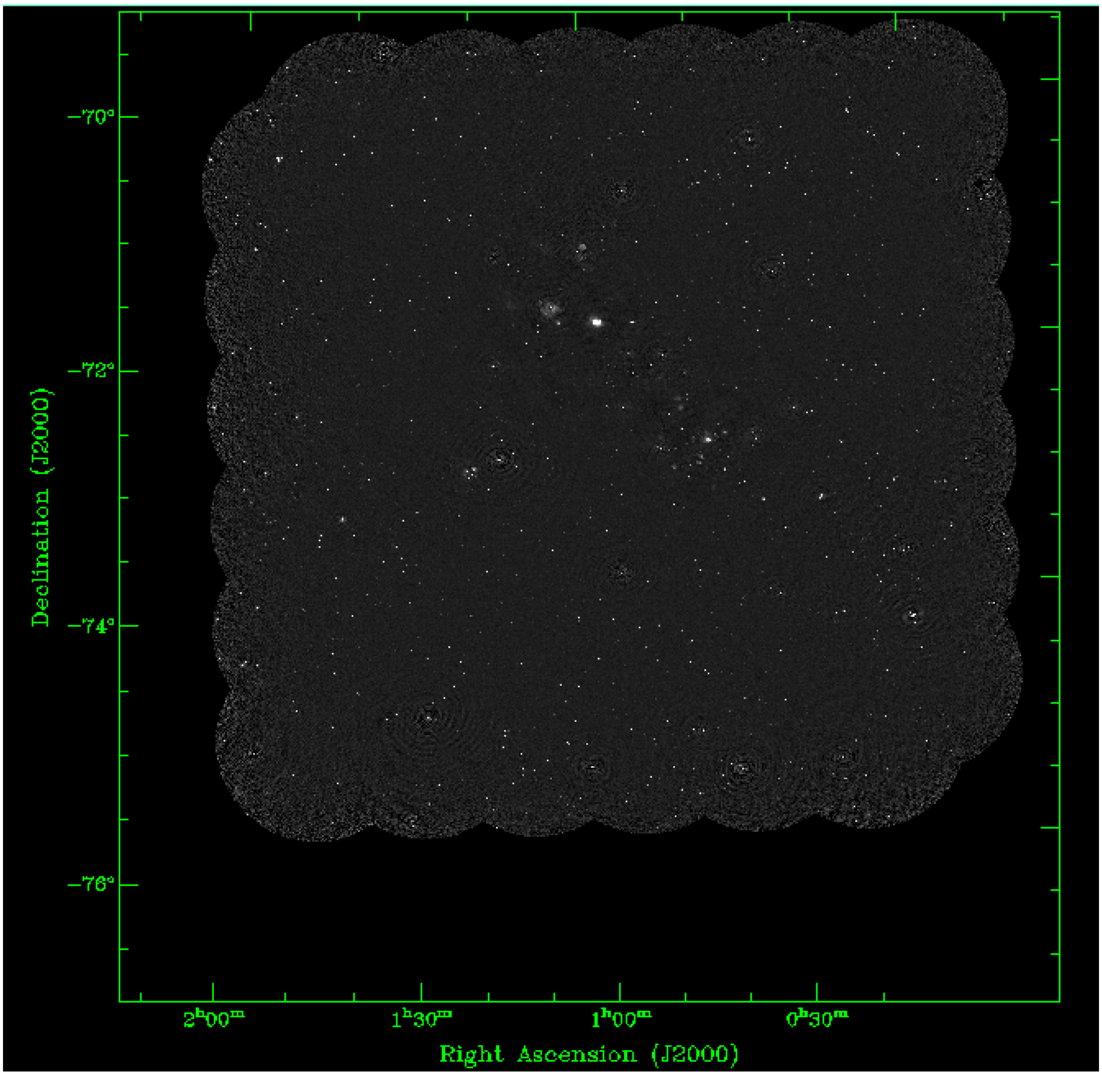


Figure 2: a 12-hour observation of the Small Magellanic Cloud, using 12 antennas at a bandwidth of 240 MHz, courtesy of Evan Crawford, Jordan Collier, and the ACES team. The rms of the image is about 100uJy/beam.

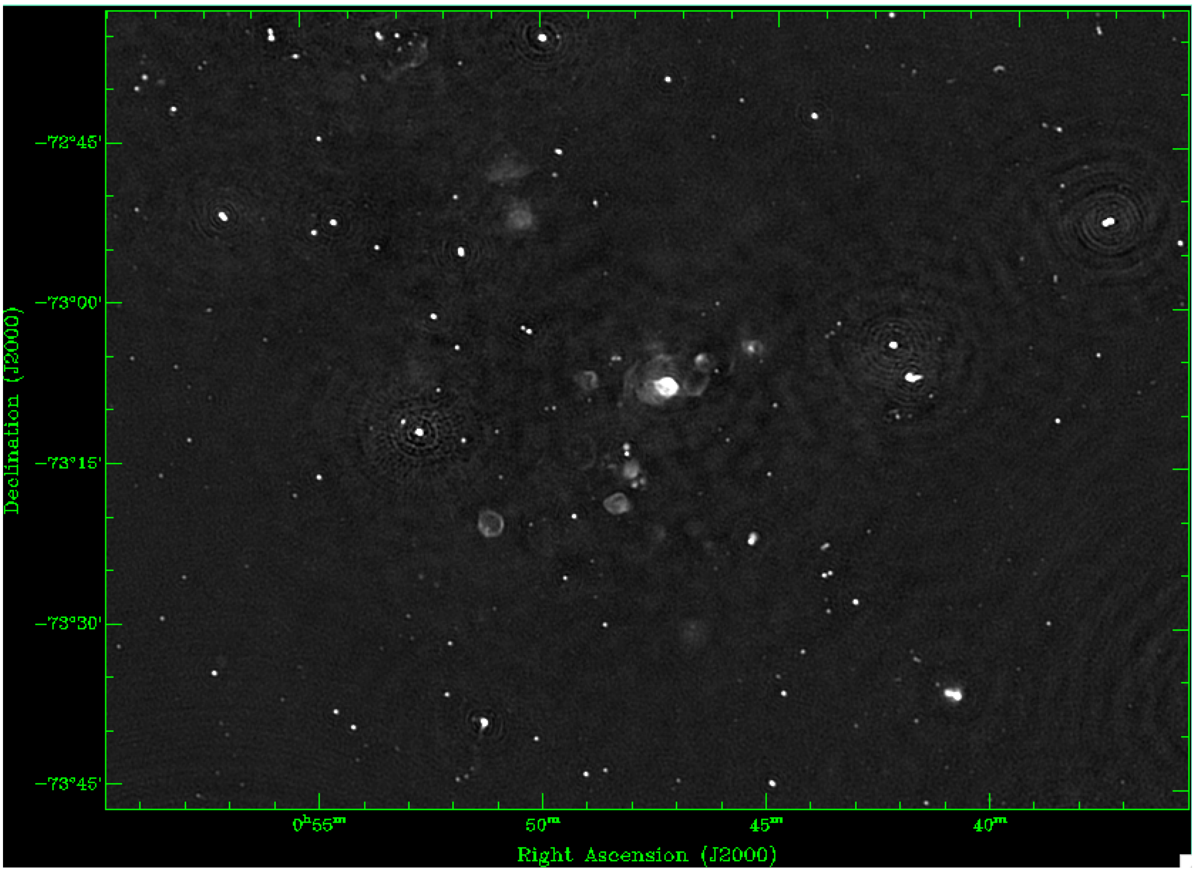


Figure 3: A small area of Fig. 1 showing shells of diffuse emission due to supernovae, HII regions, and planetary nebulae. Five planetary nebula have already been discovered in this data

will be an opportunity to revisit existing plans, incorporate new opportunities, assess how we interact with the other science survey teams, and determine how best to use the telescope to deliver world-beating science.

Meanwhile, we are revisiting some of the EMU processes and policies, have started to modify the EMU publication policy, to reduce complexity and overheads, and lower the barriers to producing science with the ASKAP. For example, we are renaming the 'Team Science Projects' to simply 'Science Projects and invite people to propose projects for science that they would like to do with the EMU data, using the form on http://askap.pbworks.com/ProposedProjects. We also invite people to submit projects to use Early Science data on the existing Early Science fields using the same form.
We are also going to simplify the EMU publication policy.

A few weeks ago, all EMU members were invited to vote on a significant change, and voted, almost unanimously, to allow all core EMU members to have the opportunity to join any EMU science paper. Rather than spamming the entire EMU. membership on further changes, we will consult the EMU consultative group – the EMU "EGG" (see http://askap.pbworks.com/EGG).

If you are not a member of the EGG and would like to be, please email me.

With best wishes
Ray

Editorial from the Project Manager

Dear EMU Member,

We are entering an exciting time for the EMU project. The science verification phase for EMU have now started, and the first EMU busy week took place in October 2017 (Jordan Collier gives a great summary on this in present newsletter). We are now closer than ever to starting the EMU early science phase in 2018.

I would like to give you a brief Project Manager update. A few years ago EMU underwent a re-accelaration and restructure to better organize and facilitate development and science exploitation of the survey. We now have 10 active Development Projects that focus on the most crucial technical issues for the survey and that are expected to support the science projects. Further, we have 14 Key Science Projects addressing the major science to be delivered by EMU, and 12 Collaboration Projects that are to ensure readiness of auxiliary surveys and data for the EMU science. This list is never final, and if you do have a great idea we encourage you to propose it as a formal project either as one of the Development, Key Science or Collaboration projects, or –if a scope is somewhat smaller– as a Science Project. At present there are 7 Science Projects active. The Science Projects can be easily proposed through an online form on the pbworks wiki page

http://askap.pbworks.com/

As we want all these projects and great ideas to be as fruitful as possible, all projects now undergo regular progress reviews. The purpose of this is twofold; on the one hand we want to ensure the projects are alive and progressing, on the other should any difficulties or problems arise, it is best if they are acted upon as early as possible. For the ease of monitoring this review process a traffic light system has been devised, where each reviewed project is assigned either green, yellow or red light depending on its progress. Each project has assigned a management contact (a member of the EMU Management Team), and at this point each active project has been reviewed at least once. It is my pleasure to report that some great work is being done.

As of October this year, the EMU-wide meetings are happening regularly once a month. It is worth joining these telecons for the updates on the EMU observing and processing, and progress and developments of the EMU projects. To allow all members from a variety of time zones to join at least some of the meetings, the telecon time alternates each month between times optimized for the European and American members. We are hoping to be seeing more and more members dialing in the next months as EMU is ramping up.

EMU is an open collaboration, and it is definitely not too late to join the work, both technical and scientific. I encourage everyone to get involved in the projects within EMU, if you haven't yet done so, or propose your own one, and to check out the new science verification data. It is also a perfect time to get your hands dirty with the ASKAP data processing in the preparation for early science, or to start testing your methods on the actual ASKAP data before the early science phase begins.

With all the best wishes,
Anna Kapinska

ASKAP/EMU Science updates

By Jordan Collier

In this update, I will review ASKAP's current capabilities and estimate when the continuum early science observations will commence.

One dataset was a long-track observation of the Southern Hemisphere's primary flux density calibrator, PKS 1934-638, which is regularly observed to measure the system's response, and compare it to the well-known and predictable behaviour of this source, allowing all proceeding measurements to be placed on a common and absolute scale. Using these observations, Wasim Raja was able to produce an image with a dynamic range (brightest pixel divided by local noise level) of 70 000, which serves as an important demonstration that ASKAP is capable of producing high-quality datasets.

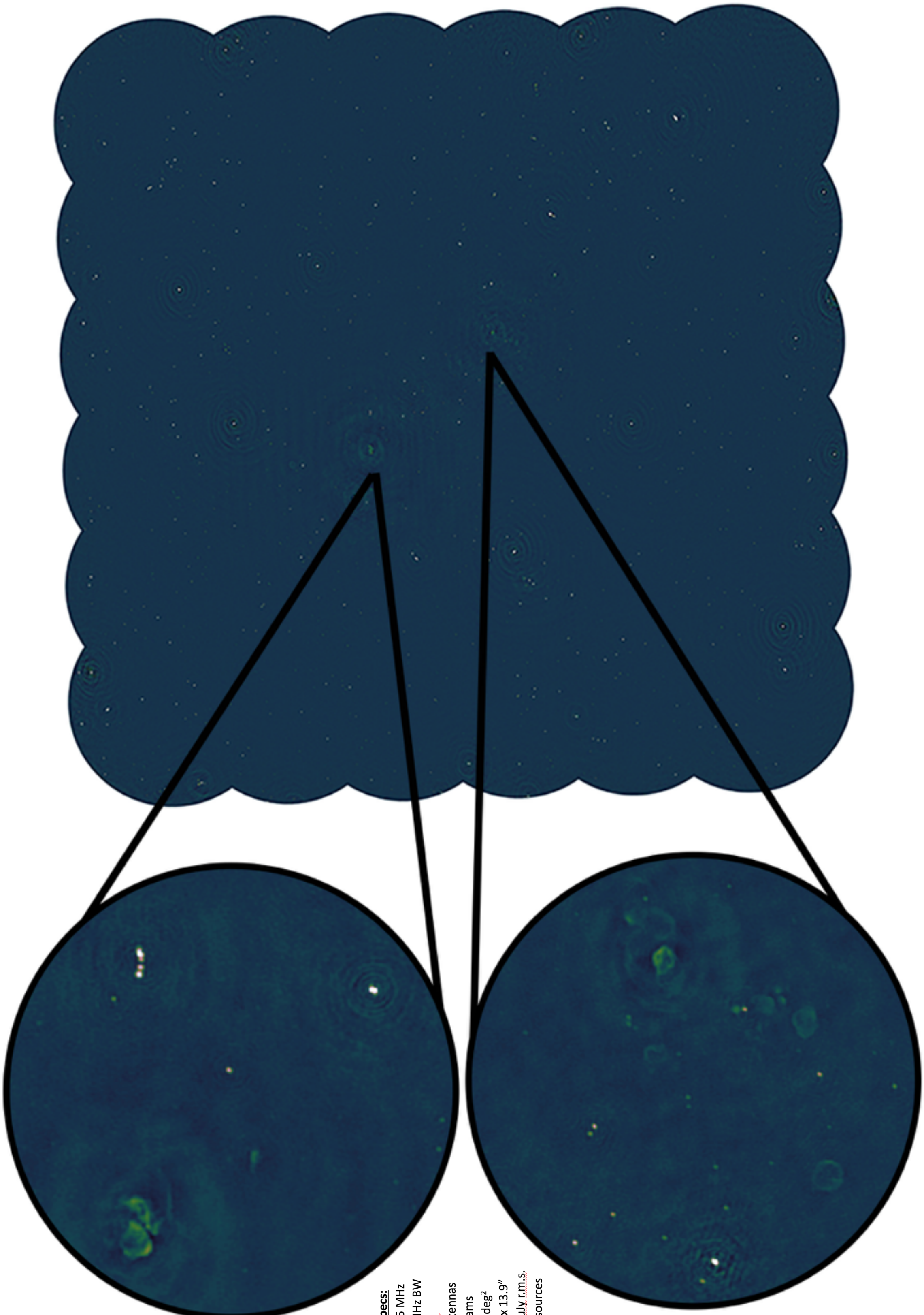
The ASKAP images of several important and well-studied fields (the Small Magellanic Cloud, Chandra Deep Field South, GAMA G23 and SPT/XXL) are already overtaking the best data previously available, and extend our knowledge of the spectral behaviour of radio sources to frequencies not previously observed at this sensitivity. The processing of these data, led by Jordan Collier and documented here, currently requires manual intervention and can easily lead to a large backlog of data processing. EMU members are therefore encouraged to get their hands dirty with processing the data, which may lead to publications. Figure 5 shows the final image resulting from one such verification observation of the Small Magellanic Cloud.

ASKAP recently implemented a new data capture mode, whereby one measurement set (a raw data file) is written for each of the 36 beams. This has already allowed us to overcome the ingest rate that was mainly limited by the speed at which a single file could be written, and already the bandwidth has increased from 192 to 240 MHz.

EMU members interested in hands-on data processing or data validation are encouraged to join a new cross-survey working group (see http://askapdp.pbworks.com for details).

Figure 4: ASKAP radio telescope 36 dishes in Murchison scrub (image credit https://sciencesprings.wordpress.com/tag/icrar/).

ASKAP EMU Evolutionary Map of the Universe



Some specs:

- 1320.5 MHz
- 192 MHz BW
- 10 hrs
- 12 antennas
- 36 beams
- 36.11 deg^2
- 18.8" x 13.9"
- ~165 uJy r.m.s.
- 3473 sources

Figure 5. This is a 1.32 GHz image of a 36-beam mosaic of one observation of the Small Magellanic Cloud, showing the full 36 square degree field of view of ASKAP. This continuum image was formed from some of the WALLABY Early Science observations, using 192 MHz of bandwidth. 12 antennas with 36 formed beams were used for observations to deliver a uniform sensitivity pattern on the sky, in this image of 18.8 arcsec X 13.9 arcsec resolution, using about 10 hours of telescope time. The RMS noise level in the image is 165 micro-Jy / beam, and there are 3473 unique radio components above the 5-sigma level (image credit

ASKAP EMU Evolutionary Map of the Universe

EMU busy weeks are periods when EMU members are encouraged to come to Marsfield to get familiar with ASKAP data and learn about the hands-on use of ASKAP with the help of experts and expert users. This involves processing data via ASKAPsoft, followed by analysis, validation, and science verification.

An EMU busy week was recently held from 3rd to 6th October 2017, in collaboration with busy weeks run by the ASKAP spectral line working group (led by WALLABY, including FLASH, DINGO and GASKAP projects), and the polarization working group led by POSSUM. During the busy week, EMU members visited Marsfield to get familiar with ASKAP data and learn about the hands-on use of ASKAP with the help of experts and expert users.

Participants spent the week learning how to access and validate the data, and how to process it on the high-performance computers at the Pawsey Supercomputing Centre. The data processing was challenging and some participants successfully managed to get high-quality images out of the process. One example comes from Evan Crawford of Western Sydney University, who processed one of the newest datasets from a new data capture mode. Figure 6 shows the inner 6 beams from this dataset, centered on the Chandra Deep Field South. At least one paper (on the star formation rates in the GAMA field) is already in preparation, and we hope more will soon be on the way. Equally important were the lessons learned, which will be addressed in subsequent iterations of our software and processes.

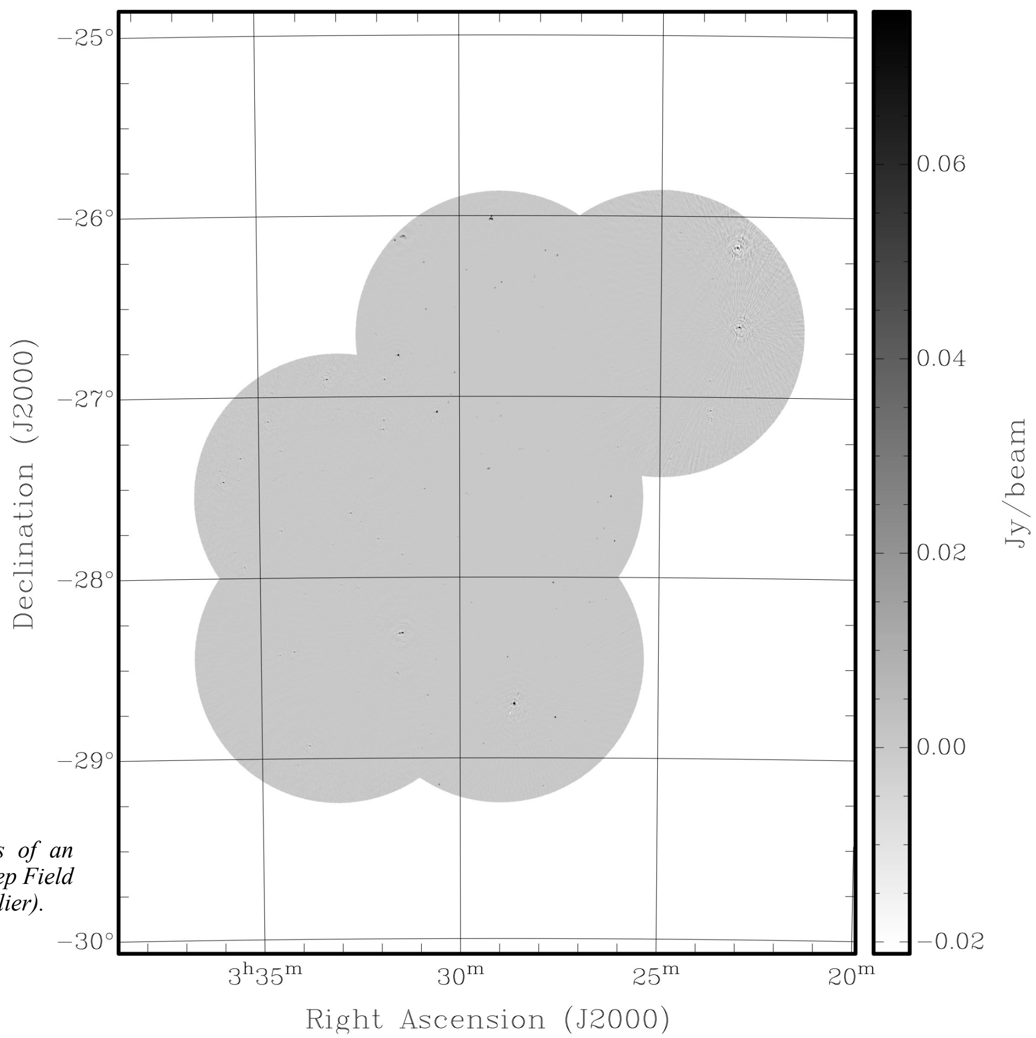


Figure 6: The inner 6 beams of an observation of the Chandra Deep Field South (image credit Jordan Collier).

ASKAP/EMU Key Projects updates

KSP4: EMU Cosmic-Web
Project Leader: Shea Brown

The EMU Cosmic-Web KSP has begun to pick up recently as the ASKAP Early Science period approaches. We welcome Professors Duncan Farrah and Shunsaku Horiuchi from Virginia Tech who have joined the KSP with an interest in using EMU to detect cosmic voids. Together with a graduate student they will be looking at Early Science data to assess the possibilities for EMU to aid in void detection.

The recent stacking detection of the Warm-Hot Intergalactic Medium (WHIM) using Planck data (Tanimura et al. 2017; de Graaff et al. 2017) gives new promise for using stacking to detect the relativistic plasma associated with the WHIM, an effort in the this KSP lead by Franco Vazza.

The pipelines needed to cross-correlate EMU maps of diffuse emission with large-scale structure have been tested recently on other data-sets; the EoR field from the Murchison Wide-field Array (Vernstrom et al. 2017), and the S-PASS survey with Parkes (Brown et al. 2017). The experience gained from these projects will be applied directly to the EMU cross-correlation experiment, starting with piggy-backing off the Cosmology Early Science fields.

Brown, S., Vernstrom, T., Carretti, E., et al. 2017, MNRAS, 468, 4246
de Graaff, A., Cai, Y.-C., Heymans, C., & Peacock, J.~A. 2017, arXiv:1709.10378
Tanimura, H., Hinshaw, G., McCarthy, I.~G., et al. 2017, arXiv:1709.05024
Vernstrom, T., Gaensler, B.~M., Brown, S., Lenc, E., & Norris, R.~P. 2017, MNRAS, 467, 4914

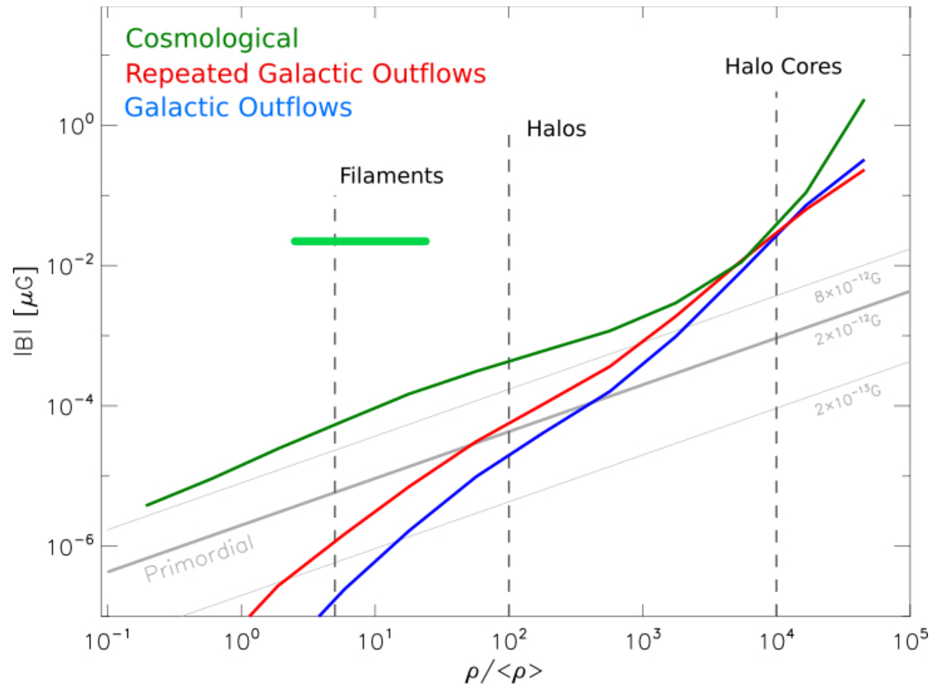


Figure 7:Plot of average magnitude of magnetic field as a function of fractional density for cosmological simulations of magnetic field evolution (Dolag et al. 2004, 2005; Donnert et al. 2009). The horizontal green bar is the 3σ upper limit derived in Brown et al (2017) through cross-correlation using S-PASS.

KSP7: Evolution of radio-loud AGN
Project Leader: Anna Kapinska

KSP 7 is a large science project encompassing major, still unresolved issues of the evolution of radio-loud AGN. The specific main goals of this project lie around measuring Radio luminosity Function (RLF) and mechanical output or Kinetic Luminosity Function (KLFs) of these sources as a function of redshift, host and environment, and investigating what triggers radio-loud AGN and what are their duty cycles. Of course no work on this subject would be complete without investigations of the AGN feedback; radio-loud AGN have a profound influence on their environments, and the Universe as a whole.

Radio-loud AGN have been researched for well over 50 years, and while an enormous amount of work has been done, the studies have always been limited either by depth or by volume of the available data (typically, the surveys have been either deep but of small area, or wide but shallow). If EMU reaches its planned depth of 10 microJy, we'll be able to recover the whole population of radio-loud AGN (both FRIs and FRIIs, or HERGs and LERGs) with radio luminosity densities >10^23 W/Hz (3σ) out to redshift z~1.0 over the whole 3π sky! This will uncover a whole new population of low power radio sources at higher redshifts that are claimed to produce bulk of the radio-loud AGN population power. Of course, the population of higher power AGN will be uncovered up to much higher redshifts.

To deliver such ambitious science goals, and the answers to everything on radio-loud AGN, a lot of preparatory work is required. KSP 7 relies on many development projects within EMU that will allow for creation of initial samples for all the analyses. Redshift identification, AGN/SF galaxy classification and separation, and spectroscopy are only some of the problems to be tackled. Radio-loud AGN require intricate cross- and self-identification methods (see updates by Ray Norris on this development project in this newsletter), and further estimates of their physical properties. For the latter problem we have seen some great progress done in recent years by the group of one of our KSP members Stas Shabala (U.Tas). We are further planning to use these developments for the EMU AGN work.

The science verification and early science phases for EMU are crucial to move on the project. Preliminary works have already started on selected fields that were observed in the past few months. Best images possible were produced at the first instance, before moving on to source extraction and application of further methods.

There are also a number of collaboration projects currently ramping up, that are particularly important for the KSP 7 and its initial work on RLFs and spectral energy distributions (SEDs). These collaboration projects include higher resolution MWA survey (70-230 MHz; discussed in this newsletter by Nick Seymour), VLA Sky Survey (2-4 GHz) and smaller area GLASS survey (5-9 GHz), all of which can hopefully be used during the early science period for KSP 7.

In addition, a recent development very relevant for the activities of KSP 7 is work on AGN/SF separation being done by PhD student Andrew Butler (UWA) under the supervision of Minh Huynh (GLASS leader) and Anna Kapinska; the paper describing an intricate decision tree for this crucial classification even without available spectroscopy is now being submitted, and hopefully will be out soon (Butler et al., A&A, submitted) and can be successfully used for the EMU work.

KSP 7 always welcomes new members. Everyone is encouraged to get in touch and join the team.

KSP8: Radio AGN in the EoR

Project Leader: Jose Afonso & Stergios Amarantidis

Key Science Project 8 "Radio AGN in the EoR", aims at developing the best approaches to identify and study the earliest AGN in the Universe using EMU.

This is fundamental to -

(a) understand the role of primordial black holes as seeds of galaxy formation and early evolution;

(b) identify the sources responsible for the Re-ionization of the Universe;

(c) constrain the mechanisms to grow the first supermassive black holes;

(d) allow for the direct study of neutral hydrogen and its evolution in the Epoch of Re-ionization itself, through observations of the HI 21cm forest against radio background sources.

The first step to identify the earliest AGN is to predict their abundance and detectability. Different methods have been used in the past, based on current observations and extrapolation to very high redshifts. One of them is the SKADS Simulated skies, which predicts the detection of ~160 AGN per deg2 for z>6, ~100 for z>8, and ~70 for z>10, for a radio survey complete to 10 microJy. However, SKADS Simulated Skies predictions are based on uncertain extrapolations of observations of much lower redshift galaxy populations.

The KSP8 team has started a different approach, exploring several state-of-the-art semi-analytical models and hydro-dynamical simulations.

Early results of this exercise, now in its final stages, shows that current models and simulations of galaxy formation are not able to predict the most massive AGN detected at z>6 (see Figure 8), the lacking is compatible (and can be, to some extent, understood and corrected) with a restricted simulation volume (around 500x500x500 Mpc^3 for the largest simulations), unable to reveal the most extreme sources that are currently known to exist in the early Universe.

These models show that the slow radio mode accretion is rare at z>5 (see Figure 9) with the quasar-mode dominating. We are currently working to understand how current and future deep radio surveys will detect these objects, hopefully assisting in identifying more efficient observational strategies. In this case, whole-sky surveys such as EMU will likely become and indispensable source to find very high redshift radio AGN before the advent of the SKA.

Over the coming months we will be finishing the exploitation of state-of-the-art galaxy formation models, seeking to characterize the radio emission from their very high redshift AGN, and the consequent detectability by EMU. If you would like to help the team with this effort, please email us.

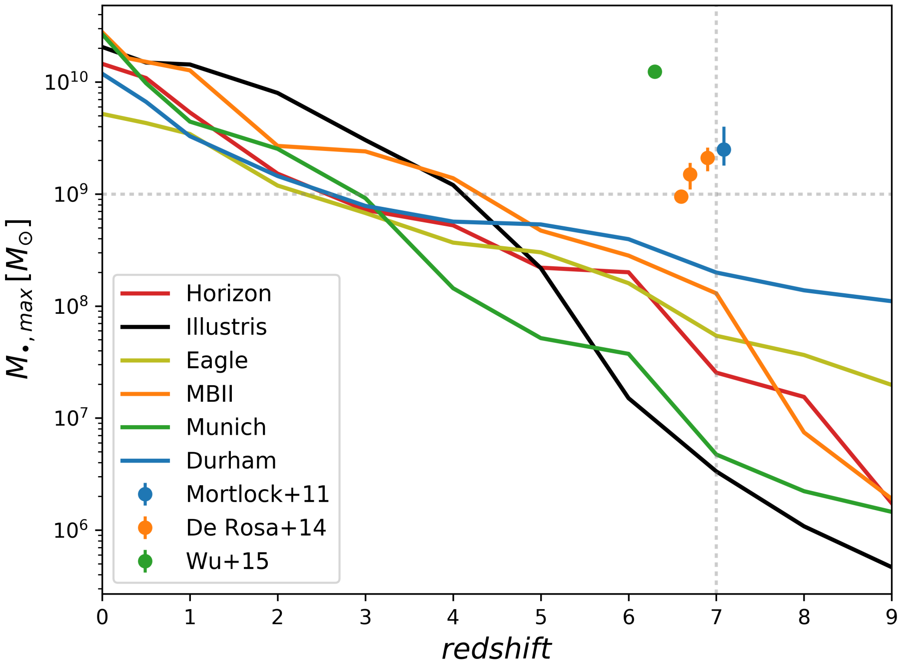


Figure 8: Comparison between the maximum supermassive black hole masses found in several state-of-the-art semi-analytical models and hydro-dynamical simulations and four of the most massive quasars known at very high redshifts.

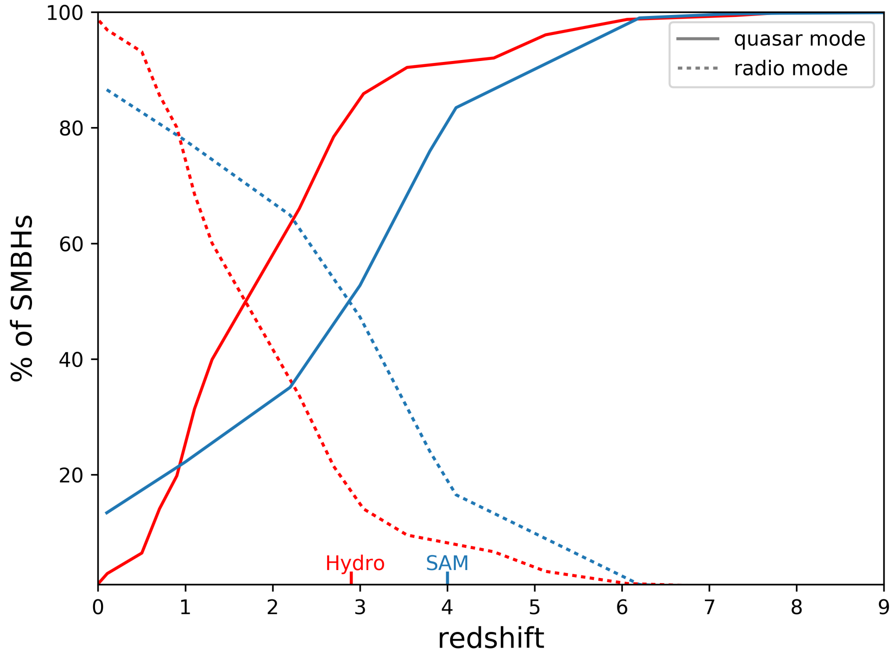


Figure 9: Percentage of SMBHs with luminosities driven by fast quasar-mode accretion (solid lines) or slow radio-mode accretion (dashed lines) for one of the hydro- dynamical simulations (red lines, Horizon-AGN, Volonteri+ 2016) and one of the semi-analytical models (blue lines, Durham, Fanidakis+ 2013) considered. The x-axis tick indicates the redshift for which 80% of the SMBHs are dominated by quasar-mode accretion. One can see that the simulations include only a residual presence of radio-mode accretion dominated SMBHs at the highest redshifts. This figure shows a remarkable resemblence to the observational result shown in Figure 12 of Rees +2016; 2016; MNRAS.455.2731R.

ASKAP Collaboration Project- Murchison Wide-field Array (MWA)
Project Leader(s): Nicholas Seymour

The Murchison Wide-field Array (MWA) is a low-frequency companion to ASKAP also located at the Murchison Radio-astronomy Observatory in Western Australia. Consisting of 256 tiles of 16 dipoles it shares ASKAP's instantaneous wide field-of-view, and fast survey speed but can observe across 70-330 MHz. With its large number of tiles it has superb snapshot uv-coverage image and can make high dynamic range images from a short (<=2mins) snapshots.

Its frequency range complements that of ASKAP and together these two radio telescopes can provide broad band radio SEDs of potentially millions of radio sources. In its phase 1 (128 tiles in a compact configuration) MWA conducted the GaLactic and Extra-galactic All-sky MWA (GLEAM) survey (Wayth et al., 2015). GLEAM imaged the entire southern sky across 71-231 MHz and provides images and photometry in 20 8 MHz sub-bands. The first data release of GLEAM comprised around 25,000 deg^2 of the extra-galactic sky and more than 300,000 catalogue radio sources with 20 band photometry (Hurley-Walker et al., 2017). For more details on GLEAM see: http://www.mwatelescope.org/science/gleam-survey

This first data release was based on the first year of the GLEAM survey. The second year increased the total exposure time by a factor of three. The most sensitive 5000 deg^2 of the extra-galactic sky has been processed with GLEAM year 1 and 2 data to provide similar data products (images and photometry across the full frequency range) as the first data release, but going twice as deep (T. Franzen et al. in prep). The greater than square root time increase in sensitivity comes from enhanced data processing including improved cleaning and calibrating off the year 1 GLEAM data.

In early October 2017 the long baselines of MWA were commissioned, improving the resolution by a factor of two. With the improved resolution we will no longer be limited by side lobe and natural confusion. The improved distribution of the phase 2 tiles for imaging means we gain sensitivity by not having to down-weight short baselines. In 2018 we plan to commence a deeper, higher resolution all-sky survey in the drift-scan mode of GLEAM as well as perform deeper pointed observations over deep multi-wavelength fields (in particular the GAMA survey regions). At present we are examining the pilot phase 2 data recently taken in both these modes including from the GAMA23 field. Our hope is that these data can be studied in conjunction with the ASKAP early science data to perform unique broad-band studies of numerous radio sources. While improving its resolution the MWA will maintain its advantage over other low-frequency facilities of wide field-of-view, frequency coverage and surface brightness sensitivity.

Figure 10: GLEAM all sky image Credit: Natasha Hurley-Walker (Curtin / ICRAR) and the GLEAM Team.)

Development Project 7: Classifying and Cross-identifying Radio Sources
Project Leader(s): Ray Norris

The primary goal of Development Project 7 is to develop techniques to cross-identify EMU sources with their host galaxies as seen in optical and infrared data. This is harder than it sounds, because about 10% of radio sources are complex sources, such as the double-lobed FRI and FRII sources, with several components, one of which may be coincident with the host galaxy. All too often, there is no radio component associated with the host galaxy.

This gives rise to a second problem. Given a pair of radio sources, how can you tell if they are the two lobes of an FRII radio galaxy, in which the radio core may be below the detection threshold, or are two star-forming galaxies? Clearly the problem of cross-identification is intimately tied up with the process of classifying the galaxies. If the two radio sources each have an infrared source coincident with them, then the chances are they are two star-forming galaxies. If they have no infrared source coincident with them, but there is an AGN half-way between them, then the chances are that they are the two lobes of an FRII, as shown in Figure 11.

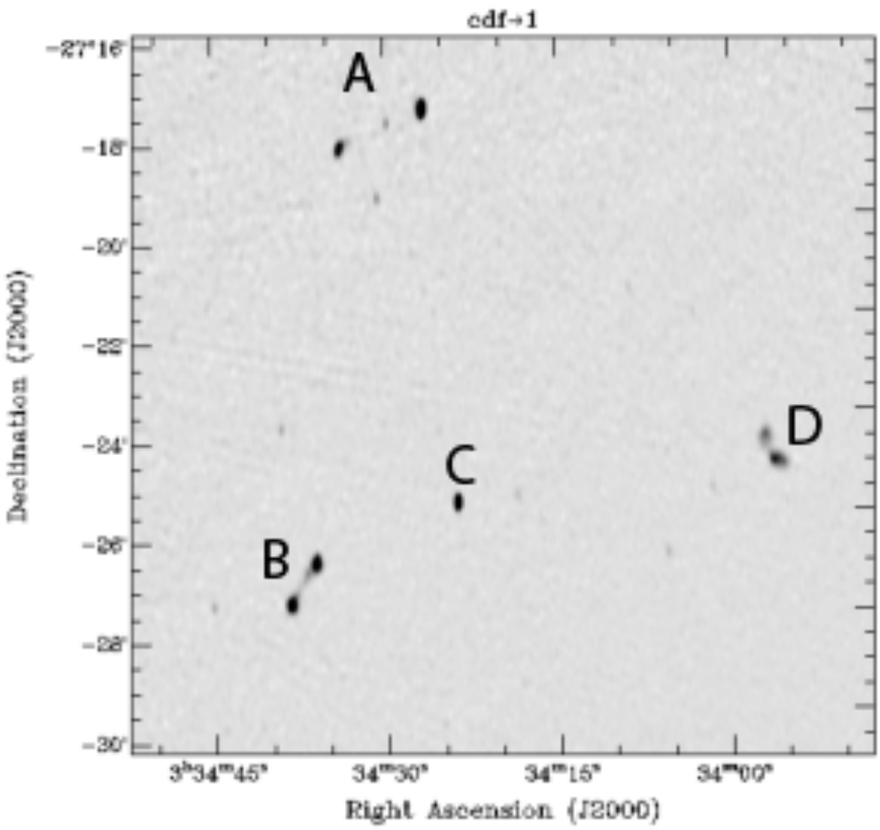


Figure 11: A typical patch of radio sky at the sensitivity of EMU. The three components of Source A show that it's unambiguously an FRII. C is a single source, so its host is probably coincident with it, regardless of whether it's a star-forming galaxy or an AGN. What about B – is it an FRII with jets or a pair of interacting star-forming galaxies. What about D – are those two star forming galaxies or the two lobes of an FRII? These questions are answered during the cross-identification process, when we find out whether there is a host coincident with each radio component, or a host midway between them..

Within DP7, we are trying out several techniques to tackle this problem. First, we need a reliable "gold standard"data set for training and evaluating algorithms. on which this cross-matching and classification process has been done manually by expert eyes. An early version of this was the first data release of ATLAS (Norris +2006, Middelberg+2008). From that experience, we learnt that infrared images give much more reliable identifications than optical images, and that techniques such as the Magliochetti test (Magliochetti+98), which work well on shallower surveys, do not work well on deep surveys. We are now developing a larger and deeper training set based on the third ATLAS data release (Franzen+2016) which is being led by University of Tasmania PhD student Jesse Swann.

An even larger training set can be provided by citizen science, and the very successful Radio Galaxy Zoo project, led by Julie Banfield (ANU) and Ivy Wong, was set up within EMU for this purpose. But even with the 10,000+ citizen scientists working on Radio Galaxy Zoo, it will still not be able to cope with the 70 million radio sources we expect from EMU, although it will probably be valuable for the unusual sources and can also produce a wonderful training set. Instead, for the majority of sources, we need to develop an automated technique.

The first approach we tried for doing this was a Bayesian approach (Fan+2015) in which, subject to some priors, we evaluated the probability of several associations between radio components and infrared components. That approach proved successful on some but not all sources, and a more sophisticated approach is under development by Dong-Wei Fan and his collaborators.

Another approach is to use the likelihood ratio. This has already been verified on single sources (Weston+2017) and PhD student Stuart Weston is now adapting it to multiple-component radio sources.

Machine-learning techniques are also being applied to this problem. Aniyan and Thorat (2017) from SKA South Africa, first showed how a convolutional neural net (CNN) can tackle this problem and this and other machine-learning approaches are now being developed by several members of the "Machine Learning in Astronomy" group (mlprojects.pbworks.com). For example, Gary Segal (UQ) is exploring using the complexity of pixel values to distinguish double-lobed radio sources from pair of single radio sources, Nathan Kayani (WSU) is exploring the use of convolutional neural nets to distinguish double-lobed radio sources from pair of single radio sources, and Mathew Alger (ANU) has explored the use of binary classification techniques for cross-identification, and has a paper close to submission.

The most important optical/IR surveys to be cross-matched with the main EMU survey will be WISE, VHS, and SkyMapper, while several other surveys (e.g. SDSS, DES, GAMA, etc) will also be important in areas of overlap. We will also cross-match with other radio surveys such as MWA-GLEAM, SUMSS, LOFAR, NVSS, and FIRST.

We expect that a combination of these techniques will be used. Exactly how will depend on how well they perform. An educated guess might be something like:

I. 100% of sources: Do a first pass with the likelihood ratio technique. Sources with a high reliability, or with no nearby optical/IR counterpart, are "retired" (i.e. accepted as being correct) and the remainder are passed to the next stage. (Guesstimate: 30% have no nearby candidate, 50% are correctly ID'd by the LR technique)

II. 20% of sources: Pass the tricky ones to the ML and Bayesian approaches to see if they can sort them out. Sources with a high reliability are "retired" (i.e. accepted as being correct) and the remainder are passed to the next stage. (Guesstimate: 15% are correctly ID'd by the ML/Bayesian techniques)

III. 5% of sources: Pass the tricky ones to the RGZ (together with some easy ones to keep people motivated) to see if Citizen Scientists can sort them out. (Guesstimate: 4% are correctly ID'd by the RGZ)

IV. 1% of sources: These are the really weird ones. Pass them to the astronomers or to the WTF (Discovering the Unexpected) project. This will be a rich data set for astrophysics. Trouble is, this is still 700,000 sources! Lets hope our algorithms can do better than my guesstimates! A fair number of these will probably also be artifacts.

An important step for EMU will be to set up a feedback loop so that sources which end up in the weird (or artifact) category are used to fine-tune the data validation algorithms and the XID algorithms.

Meetings and Conferences

Please send in details of any EMU-related meetings or conferences coming up.

1) EMU-wide Regular meetings

EMU monthly meetings take place on the first Wednesday of each month, with full details on

http://askap.pbworks.com/EMU_monthly_meetings

Th next EMU monthly meeting is scheduled on Wednesday 6 December 2018 at 00:00 UTC (1100 AEDT).

There will be no meeting on Wed 3 January 2018, because of the Australian holiday season, and the meeting after that will be on Wednesday 7 February 2018

ASKAP Update

ASKAP Update is a regular series dedicated to conveying the latest news about the Australian Square Kilometre Array Pathfinder (ASKAP) project to International science and engineering communities. It will also provide a deeper look at key aspects of ASKAP's development. ASKAP Update replaces the ASKAP Science Update and ASKAP Technical Update publications. The latest issue, number 9, was released in November 2015 and is available here. It does not replace any of the formal communications about ASKAP or SKA, but aims to be a more "earthy" dissemination of information about ASKAP's progress from the astronomer's perspective.

To receive notification of online publication of each new edition, please e-mail ASKAP Project Scientist Lisa Harvey-Smith to subscribe.

Publications

EMU Publications

1. Cavallaro, F.; Trigilio, C.; Umana, G.; Franzen, T. M. O.; Norris, R. P.; et. al. 2018, "SCORPIO - II. Spectral indices of weak Galactic radio sources", MNRAS; 473; 1685C
2. Norris, Ray P.; 2017, "Extragalactic radio continuum surveys and the transformation of radio astronomy", Nature Astronomy, 1, 671
3. Norris, 2017, Discovering the Unexpected in Astronomical Survey Data, 2017PASA...34....7N
4. Weston, S. D.; Seymour, N.; Gulyaev, S.; Norris, R. P.; Banfield, J.; et al., 2017, "Automated Cross-identifying Radio to Infra-red Surveys Using the LRPY Algorithm: A Case Study", MNRAS, in press, (arXiv:1710.01449)
5. Raccanelli, et al., 2017, Future constraints on angle-dependent from large radio surveys, PDU....15...35R
6. Norris, 2016, Astroinformatics Challenges from Next-generation Radio Continuum Surveys, arXiv161200048N
7. Crawford et al 2016,WTF? Discovering the Unexpected in next-generation radio continuum surveys, arXiv161102829C
8. Riggi et al., 2016, Automated detection of extended sources in radio maps: progress from the SCORPIO survey
9. Vazza et al. 2016, "Detecting the cosmic web with radio surveys", PoS, 2016
10. Umana et al. 2015, "SCORPIO: a deep survey of radio emission from the stellar life-cycle" ,MNRAS, 454,902
11. Dabbech et al., 2015, MORESANE: MOdel REconstruction by Synthesis-ANalysis Estimators. A sparse deconvolution algorithm for radio interferometric imaging
12. Banfield et al. 2015, "Radio Galaxy Zoo: host galaxies and radio morphologies derived from visual inspection", MNRAS, 453,2326
13. Hopkins et al. 2015,"The ASKAP/EMU Source Finding Data Challenge", PASA, in press (arXiv:1509.03931)
14. Fan et al. 2015, Matching radio catalogues with realistic geometry: application to SWIRE and ATLAS, MNRAS, 451, 1299
15. Vazza et al. 2015, "Forecast for the detection of the magnetised cosmic web from cosmological simulations," A&A, 580, A119
16. Raccanelli et al., 2015, Probing primordial non-Gaussianity via iSW measurements with SKA continuum surveys, JCAP, 01, 042
17. Rahman SF ,2015, Theoretical estimates of integrated Sachs–Wolfe effect detection through the Australian Square Kilometre Array Pathfinder's Evolutionary Map of the Universe (ASKAP- EMU) survey, with confusion, position uncertainty, shot noise, and signal-to-noise ratio analysis, CJP, Vol 93. No. 4, pp. 384-394 (ads)
18. Dehghan et al., 2014,"Bent-tailed Radio Sources in the Australia Telescope Large Area Survey of the Chandra Deep Field South" , AJ, 148, 75
19. Ferramacho et al., 2014, "Radio galaxy populations and the multitracer technique: pushing the limits on primordial non-Gaussianity", MNRAS, 442, 2511 (ads)
20. Norris et al., 2013, Radio Continuum Surveys with SKA Pathfinders, PASA, 30, 20 (ads)
21. Cassano et al., 2012, Radio halos in future surveys in the radio continuum, A&A, 548, 100 (ads)
22. Huynh et al., 2012, " The completeness and reliability of threshold and false-detection-rate source extraction algorithms for EMU compact sources", PASA, 29, 229 (ads)
23. Camera et al., 2012, "Impact of Redshift Information on Cosmological Applications with Next-Generation Radio Surveys", MNRAS, 427, 2079 (ads)
24. Hales et al., 2012, "BLOBCAT: Software to Catalogue Flood-Filled Blobs in Radio Images of Total Intensity and Linear Polarization", MNRAS, 425, 979 (ads)
25. Raccanelli et al., 2012, "Cosmological Measurements with forthcoming Radio Surveys", MNRAS, 424, 801 (ads)
26. Hancock et al., 2012, "Compact continuum source finding for next generation radio surveys", MNRAS, 422, 1812 (ads)
27. Hollitt & Johnston-Hollitt, 2012, "Feature Detection in Radio Astronomy using the Circle Hough Transform", PASA, 29, 309 (ads)
28. Norris et al., 2011, "Evolutionary Map of the Universe: Tracing Clusters to High Redshift", JApA, 32, 599 (ads)
29. Norris et al, 2011, "EMU: Evolutionary Map of the Universe", PASA, 21, 215 (ads; The EMU survey description paper)

Key Links

Main EMU wiki: http://www.askap.pbworks.com

ASKAP: http://www.atnf.csiro.au/projects/askap/
anzSKA: http://www.ska.gov.au
The SKA: https://www.skatelescope.org/

Contributions

Contributions are sought from all members of the EMU Team. Plain text is preferred and submission of images and photographs is welcomed!

Deadlines

For Issue 14 please submit material by 5th March 2018. Email reminders will be sent out several weeks beforehand!

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