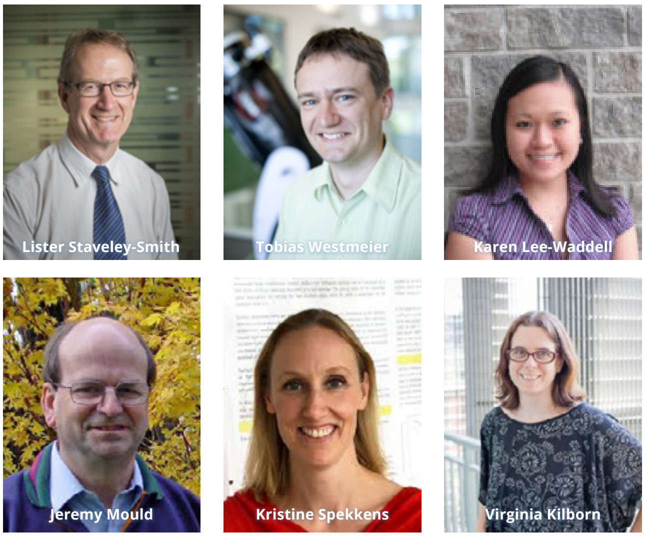
WALLABY Newsletter

No. 10, December 2018
Edited by O. Ivy Wong



WALLABY executive team members

WELCOME

It is with great pleasure that I welcome you to the November/December 2018 edition of the WALLABY newsletter. As the ASKAP instrument ramps up the number of baseline correlations, so too has this newsletter grown in the past few editions.

As usual, the ASKAP spectral line commissioning update will be presented by Attila Popping and Karen Lee-Waddell. In this edition, Tristan Reynolds and Ahmed Elagali have provided brief summaries of WALLABY's first and third early science papers, respectively.

In addition, we also feature updates from Claudia Lagos on the simulations group's latest activities, as well as updates from the source finding and cataloguing working group by Tobias Westmeier. Kristine Spekkens will also introduce the new Canadian initiative called CIRADA.

As always, if you have any submissions or announcements for the next issue in 8 months' time, please do not hesitate to email them to me. Happy reading and wishing you all a happy holiday season!

- O. IVY WONG

MESSAGE FROM THE WALLABY PI

Lister Staveley-Smith

Welcome to another Wallaby newsletter, and thanks again to Ivy Wong for being editor. It's my pleasure to introduce the new Wallaby project scientist, Karen Lee-Waddell and the new Wallaby project manager, Tobias Westmeier. Together with the PI(s), they will form the management group which will meet on a weekly basis.

Three additional executive members have also been appointed to offer strategic advice on a regular basis: Kristine Spekkens, Jeremy Mould and Virginia Kilborn. Welcome to them also.

The last few months have been a busy period for the Wallaby early-science team who have been working hard to conclude reductions of the four Wallaby early science fields (NGC 7232, M83, Fornax and Dorado). Numerous problems have been solved with the help of the CSIRO ACES team and the ASKAPsoft development team.

The three or so papers that have now been submitted (with a similar number in preparation) are a fantastic early indicator of the quality science that Wallaby will produce.

Effort is now moving towards defining the Wallaby pilot survey project for which we have been allocated 100 hrs of time with the full ASKAP array to prove survey readiness. One of the major problems to be addressed is the current inability of processing to keep up with 24/7 Wallaby data flow until the Pawsey upgrade is completed. Additional short-term processing options are being considered.

Although science output is not the main priority for CSIRO in conducting the pilot survey phase, we will be choosing a variety of fields, all of which will be scientifically interesting and which should offer opportunities for participation by the broader Wallaby team. We will keep you posted!

EARLY SCIENCE WALLABY PAPER 1: THE NGC 7162 GALAXY GROUP

Tristan Reynolds

In this work, which has been accepted for publication in Monthly Notices of the Royal Astronomical Society (https://doi.org/10.1093/mnras/sty2930), we present results from ASKAP/WALLABY early science observations of the NGC7162 galaxy group (Figure 1). We used the observations to test and determine optimal parameters for the data reduction pipeline ASKAPsoft, perform validation of ASKAP and ASKAPsoft and investigate signs of interactions in HI among the galaxies in the NGC7162 galaxy group.

The NGC7162 galaxy group is an ideal data set for validation as there are archival observations from HIPASS on the Parkes telescope and the Australia Telescope Compact Array (ATCA), which we used to compare various neutral hydrogen (HI) properties (e.g.: integrated spectra, fluxes, systemic velocities, etc.). We found generally good agreement among the observations, however the ASKAP observations do not recover as much flux as the HIPASS and ATCA observations. This is expected as HIPASS used a single dish and the ATCA array configuration had shorter baselines than ASKAP, making them both more sensitive to diffuse emission. We also compared the results from imaging the data using ASKAPsoft with imaging performed using MIRIAD, finding excellent agreement and demonstrating that ASKAPsoft performs as well as existing data reduction software.

From the literature, the NGC7162 group was stated as being comprised of three spiral and one elliptical galaxy. We detect six galaxies in the HI 21-cm line, expanding the NGC7162 group membership from four to seven galaxies, as we did not detect HI in the elliptical galaxy. Two of the new detections are also the first HI detections of the dwarf galaxies, AM2159-434 and GALEXASC J220338.65-431128.7, for which we have measured velocities of cz=2558 km s^{-1} and cz=2727 km s^{-1}, respectively. We were unable to detect any extended HI emission around the group galaxies above the threshold of 9.5×10^{18} cm^{-2} per 4 km s^{-1} channel for emission filling the 39" × 34". Full ASKAP will be sensitive to lower column density gas, however the early science results were limited by minor calibration errors and the incomplete uv-coverage from only using 12 antennas. We were still able to take advantage of the higher resolution (factor of ~1.5) of the ASKAP observations compared with the archival ATCA data to model the kinematics of the group spirals and estimate their dynamical and dark matter masses. We find all group spirals to have dark matter fractions ~0.81-0.95.

There are a couple tentative indications of past group interactions in the form of extended HI emission around NGC7162 from the ATCA data and an offset of ~40 degrees between the kinematic and morphological major axes for NGC7162A. Additionally, the difference in integrated flux of NGC7162A between HIPASS and ASKAP indicates there is likely ~40% more diffuse emission resolved out by an interferometer. However, we did not find any spirals to have disturbed kinematics, which could be an interaction signature, and all group spirals are HI rich. We conclude that it is more likely that these galaxies are infalling for the first time and are yet to undergo any significant tidal interactions. The mosaicked image cube produced with ASKAPsoft is publicly available and can be downloaded from CASDA (https://doi.org/102.100.100/74066).

ASKAP EARLY SCIENCE COMMISSIONING UPDATE

Attila Popping & Karen Lee-Waddell

During the last period the spectral line working group has continued testing and improving the output of the ASKAPsoft processing pipeline. With the current default settings we are able to reduce many of the early science observations and achieve science quality data. Most of the processing was focused on selected beams and a selected bandwidth range containing interesting galaxies or objects.

The team continued to have weekly telecons with most participants from CASS and ICRAR-UWA. In May of this year we organised a busy week in Sydney, apart from the normal work on data processing there was extra focus on writing early science papers. Currently the WALLABY early science observations have resulted in 4 early science papers that are either accepted or under review with more on the way in the near future.

While most of the early science observations were undertaken with 12 ASKAP dishes, later observations with 16 dishes have yielded significant improvements in the image results. Not only in sensitivity, but also in data quality as the calibration and cleaning of data has become easier. We are very excited about current ASKAP observations with 28 dishes that again will give a very significant improvement on previous data and are getting very close to the final ASKAP specification.

While the primary role of the ASKAP spectral line working group has been to test different aspects of the processing pipeline and reduce part of the early science data, this focus is likely to shift with the new method of ASKAP operations. As ASKAP operators will do all the processing, the next emphasis will be will be on verification of the data and quality control.

EARLY SCIENCE WALLABY PAPER 3: NGC 1566

Ahmed Elagali

Figure 2 shows the column density map of NGC 1566 mosaic field. We detect six galaxies including NGC 1566 in this mosaic. Even though tidal interactions between NGC 1566 and the neighbouring galaxies may have occurred, we do not see any HI tail/bridge that would result from such an interaction. It is important to note that the centre of the NGC 1566 group is shown by the blue filled circle in Figure 2, as defined by where the two most massive and bright galaxies of this group are located, namely NGC 1553/1549.

Even though the surface brightness sensitivity of ASKAP observations is sufficient to detect relatively low H I column densities, we have not detected any HI emission (above our rms noise) from this interacting galaxy pair. The upper HI mass limit of NGC 1553/1549 based on our rms noise (3σ) and assuming ten velocity channel widths (40 km/s) is 3.7 × 10^6 $M_\odot$ $beam^{-1}$ at the distance of this galaxy pair (17.6 Mpc).

Figure 3 presents a deep optical image of NGC 1566 created from the UK Schmidt plates, courtesy of David Malin. We also examine this deep image and see no faint stellar substructures around NGC 1566, nor a dramatic system of streams/plumes that may have formed through a tidal interaction or minor merger with neighbouring galaxies.

It is important to note that these faint structures can form on timescales of 10^8 years and exist for few gigayears after the interaction. Hence, a recent interaction scenario is less likely to be the reason for the asymmetries seen in the outer HI disc of NGC 1566. Alternatively, the observed asymmetries in the H I disc of NGC 1566 can be a result of gas accretion or ram pressure, see Elagali et al 2019 for more details.

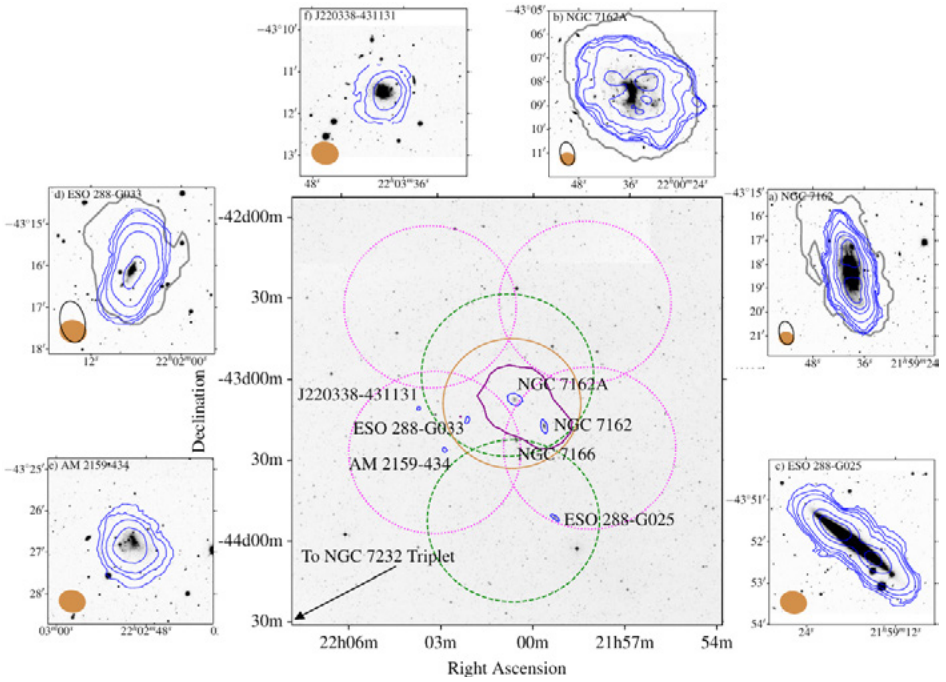


Figure 1. This figure shows a Digitized Sky Survey optical image with overlaid ASKAP (blue) and HIPASS (purple) contours. The ASKAP primary beams from the A (green dashed circles) and B (magenta dotted circles) footprints are shown, along with the archival ATCA observation primary beam (orange solid circle). The postage stamps show Dark Energy Survey images of each galaxy detected with ASKAP with integrated intensity contours overlaid from ASKAP (blue) and if observed with ATCA (grey). The solid orange ellipse in the lower left corner shows the ASKAP synthesised beam and the empty black ellipse shows the ATCA synthesised beam.

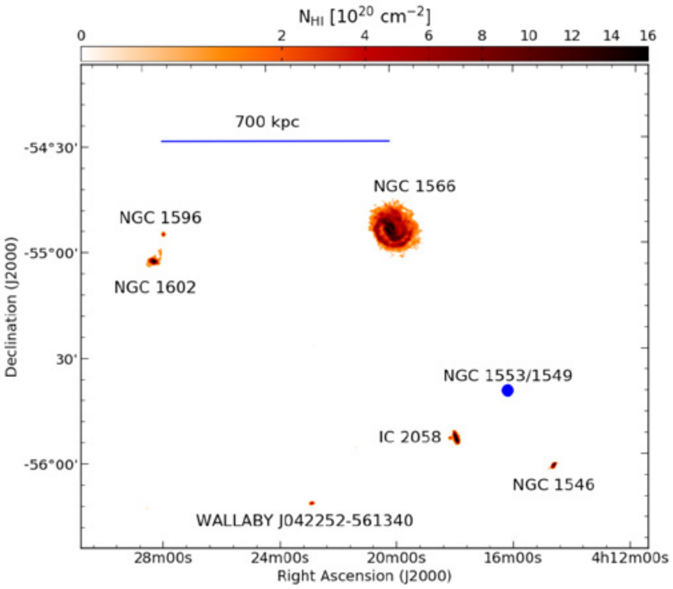


Figure 2. The HI column density map of NGC 1566 mosaic field as revealed by ASKAP early science observations. There are six galaxies detected in this mosaic, within a velocity range between 950 − 2040 km/s. The projected physical distance between NGC 1566 and the galaxy pair NGC 1596/1602 is shown by the blue horizontal line. The blue filled circle shows the centre of the group, and the location of the two interacting galaxies NGC 1553/1549.

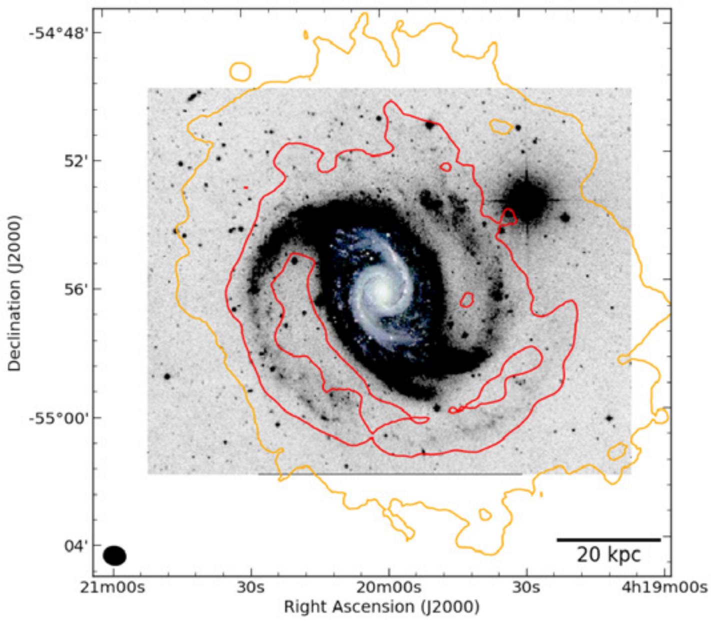


Figure 3. Deep image of NGC 1566 created from the UK Schmidt telescope and available at the Australian Astronomical Observatory database. The red and orange contours are at HI column density values of N_{HI} = 3.7 × 10^{20} cm^{-2} and 0.15 × 10^{20} cm^{-2}, respectively. The synthesised beam size of ASKAP observations is shown as an ellipse in the bottom left.

TWG 1 – THEORY & SIMULATIONS GROUP

Claudia Lagos

The theory and simulations working group of WALLABY has been making great progress recently on different areas that are directly relevant for the survey. Below we describe two highlights on the modelling of HI in semi-analytic models and hydrodynamical simulations.

SEMI-ANALYTIC MODELLING OF HI IN GALAXIES

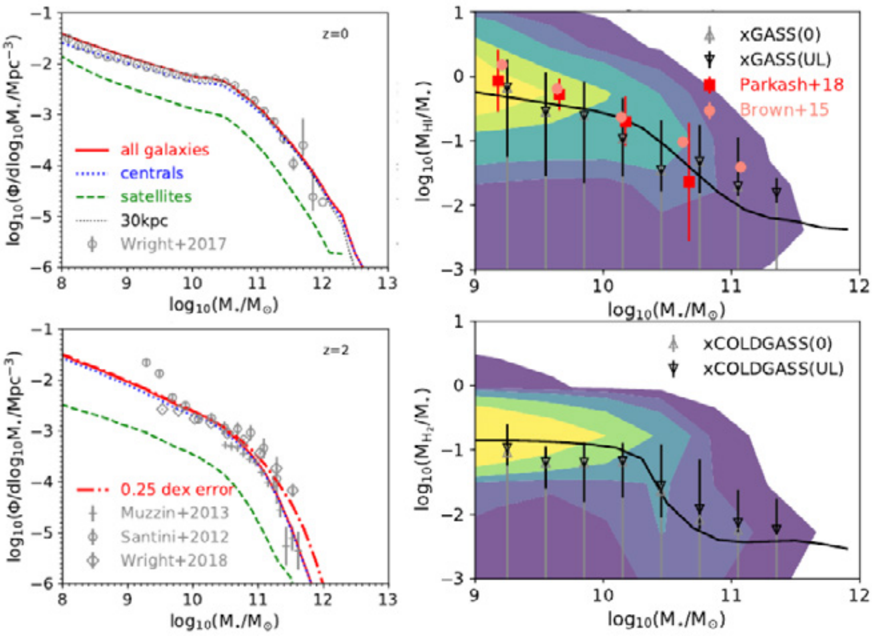


Figure 4. Left: Stellar mass functions at z=0 and z=2 for Shark galaxies, showing the contributions to satellite and central galaxies. Observations from Santini et al. (2012), Muzzin et al. (2013), and Wright et al. (2017, 2018) are shown as symbols. Right: Atomic hydrogen and molecular hydrogen mass to stellar mass ratios as a function of stellar mass at z=0 for Shark galaxies compared to Brown et al. (2015), Saintonge et al. (2017), Catinella et al. (2018), Parkash et al. (2018).

A new semi-analytic model of galaxy formation, Shark, has been developed by the ICRAR/UWA team, led by Claudia Lagos in collaboration with other theory/computing group members and Data Intensive scientists at ICRAR/UWA. This new model has been designed to be very flexible in exploring a wide range of physical processes, but also different ways of modelling each of these processes. The model also allows arbitrary levels of complexity to be implemented thanks to its numerical approach to solving the way different physical processes interact with each other. The model is open source and available to the community. The paper has been recently published in MNRAS (Lagos et al., 2018, MNRAS, 481, 3573L).

Among the most exciting findings is that this model is able to simultaneously reproduce the evolution of the stellar mass function up to z=4 and the gas properties of galaxies (see Figure 4). Shark models three phases in gas disks: ionised, atomic and molecular. The model is now being used to explore the connection between the angular momentum of the atomic gas and the stars.

From this model, ICRAR/UWA PhD student Garima Chauhan is producing a new WALLABY lightcone with HI emission line profiles and spectral energy distributions from the FUV to the FIR. This lightcone will be ready for circulation by the end of 2018 and the group will notify the WALLABY team.

ILLUSTRIS-TNG RESULTS ON THE CONNECTION BETWEEN HI IN GALAXIES AND ENVIRONMENT

ICRAR/UWA Research Postdoc Adam Stevens in collaboration with the Illustris-TNG team has improved significantly on the postprocessing of hydrodynamical simulated galaxies to account for the gas phase transition from ionised to atomic to molecular gas (Diemer, Stevens et al. 2018; Stevens et al. 2018). This has allowed a detailed study of the effect of environment on the atomic hydrogen content of galaxies that has been recently submitted to MNRAS (Figure 5; Stevens et al. 2018, arXiv:1810.12158). Stevens et al. find that the state-of-the-art hydrodynamical simulation Illustris-TNG is able to reproduce quite well the atomic hydrogen content of satellite and central galaxies as a function of stellar and halo mass. The authors then quantified the depletion of HI since the infall of satellites, showing that galaxies in groups get their HI stripped in timescales twice as long as galaxies in clusters (but with a strong secondary dependence on mass). These measurements are available for the WALLABY team upon request (adam.stevens at uwa.edu.au or claudia.lagos at icrar.org).

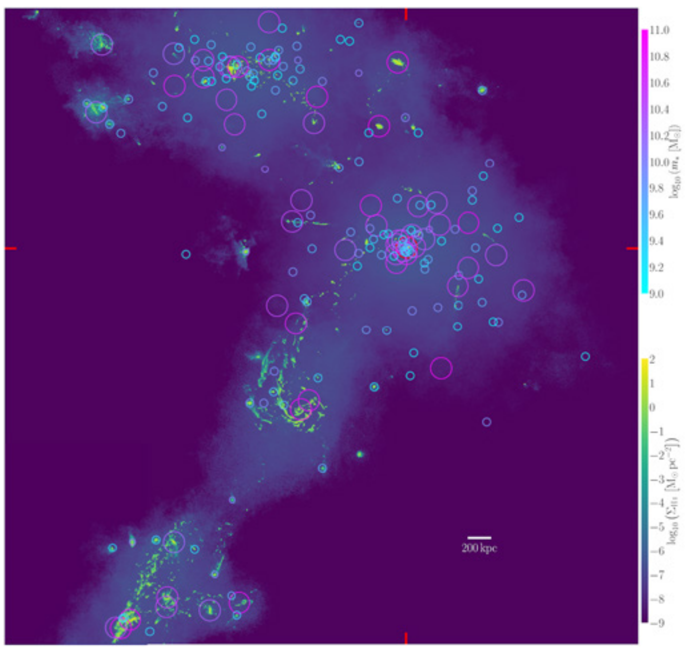


Figure 5. Projected HI column density of a low-mass cluster at z = 0. The image is 6×6 Mpc. Circles indicate the physical beam size used to measure HI masses in this cluster for the xGASS mock, and are coloured by the stellar mass of the galaxy they are centred on. The central galaxy of the cluster can be identified by the deeper red circle, located where the red edge marks would meet.

TWG 4 – SOURCE FINDING AND CATALOGUING

by Tobias Westmeier on behalf of TWG 4

RELEASE OF SOFIA 1.2

The latest stable version 1.2 of SoFiA, our source finding and parameterisation pipeline, was released on 25 May 2018 and is available on GitHub at

https://github.com/SoFiA-Admin/SoFiA/releases

The latest version comes with several new features, the most notable of which involve changes in the way SoFiA measures and corrects for noise variations across a data cube. SoFiA now allows users to measure and correct for local noise variations in a running window across the cube. This can be used to normalise the noise level in interferometric image mosaics prior to applying a source finding threshold. In addition, all noise measurement algorithms have been optimised for greater speed and can now be applied to only negative pixels, only positive pixels, or all pixels of the data cube in an attempt to make the noise measurement even more robust against outliers such as artefacts or astronomical sources. Other improvements in SoFiA include a slightly reduced memory footprint, minor changes in the pipeline control and graphical user interface (GUI), and the fixing of several bugs throughout the pipeline.

The SoFiA team is already actively working on the next release, SoFiA 1.3, which is expected to be ready before the end of this year. As a major new feature, SoFiA 1.3 will provide additional source size filtering options in the linker, e.g. the removal of sources exceeding a given size limit. In addition, the team is actively working on automated flagging algorithms for the removal of artefacts such as residual continuum emission from the input data.

SOFIA WEB INTERFACE

Users who do not have the GUI installed will be delighted to learn that we are now providing a web-based user interface that allows SoFiA parameter files to be created and manipulated online using a standard web browser. The new SoFiA web interface is available at

https://www.atnf.csiro.au/people/Tobias.Westmeier/sofia_web_interface/sofia_web_interface.html

and should work in all modern web browsers. While not quite providing the full functionality and comfort of the GUI, the web interface offers a convenient way of importing, editing and exporting SoFiA parameter settings in an interactive way. Unlike the GUI, the web interface cannot be used to run SoFiA. Instead, parameter files will need to be saved to disc where they can then be processed with the SoFiA pipeline installed on the user's own computer (which is where the data will normally be located anyway).

NAMING CONVENTION FOR WALLABY DETECTIONS

With the analysis of the WALLABY early science data well under way, the need arose to define a coherent way in which H I detections made by WALLABY can be named. We therefore officially registered the WALLABY acronym and an associated source naming scheme with the IAU. In summary, all H I detections made as part of the full WALLABY survey, or any of its early science or pilot surveys, must be given a unique name of the form

WALLABY JHHMMSS±DDMMSS

which consists of the identifier "WALLABY" followed by a space and the letter "J" to indicate J2000 equatorial coordinates. This is followed by the integer hours, minutes and seconds of right ascension, the declination sign symbol ("+" or "-"), and the integer degrees, arc minutes and arc seconds of declination of the source as measured from the WALLABY data. The last decimal of the coordinate specification must be truncated, not rounded, to comply with IAU requirements. Most importantly, the name of any WALLABY detection must be unique; once a name has been assigned to a source, that name must be used in all subsequent publications even if a slightly different or more accurate coordinate measurement becomes available. Please see the CDS website at

http://cds.u-strasbg.fr/cgi-bin/Dic?WALLABY

for detailed information about the new naming scheme. The scheme is also described in detail in WALLABY memo #21 available from the WALLABY Redmine wiki.

NEW KINEMATIC SOFTWARE DEVELOPMENT

by George Bekiaris

What can be more fun than studying galaxy kinematics? Writing the software for the kinematic analysis of course! Over the past months I have been developing the next major version of GBKFit, a high-performance software for galaxy kinematic modelling. Past versions of GBKFit have been used to study low- and high-redshift optical and submillimetre observations with great success.

The next version of GBKFit will support more complex models which will allow the software to handle a wide variety of observations, including the warped HI galaxies found in the WALLABY survey. Besides the software's scientific potential due to the great range of supported modelling strategies, GBKFit could be used to understand the computational requirements of the kinematic analysis of the entire WALLABY survey.

Finally, its ability to run on different hardware platforms, including CPUs and GPUs, could potentially facilitate the decision-making process for future Pawsey supercomputer upgrades. This exciting new major release of GBKFit should be happening early next year. Stay tuned!

CIRADA
CANADIAN INITIATIVE FOR RADIO ASTRONOMY DATA ANALYSIS

CIRADA AND WALLABY

by Kristine Spekkens

A new project in Canada called CIRADA, the Canadian Initiative for Radio Astronomy Data Analysis, will enable the construction of a kinematics pipeline and archive for resolved Wallaby detections.

The $10M CIRADA initiative stems from the realization that, with SKA precursors and pathfinders, we are in the regime where the basic data products produced by observatories can be too large or too complex for direct scientific analysis. Of particular interest to Canadian astronomers are new all-sky surveys now being undertaken with CHIME, the VLA and ASKAP, all of which have significant Canadian involvement or leadership. The aims of CIRADA are to convert the enormous data streams from these frontier programs into enhanced data products and sophisticated digital databases using a common framework. All data products, catalogues and tools will be made publicly available to the community.

Through CIRADA, a software engineer will be hired over the next few months to work with Kristine Spekkens at Queen's University to build and optimize the Wallaby resolved galaxy pipeline from the prototypes designed by the kinematics working sub-group (Kamphuis+ 2015, MN 452 3139; Oh+ 2018, MN 473 3256). This individual will join a growing network of CIRADA developers at other Canadian institutions who will focus on producing, curating and disseminating science-ready data from different radio facilities. The software engineer will also interface with researchers in Canada and beyond to ensure that the enhanced data products delivered satisfy their scientific requirements. CIRADA looks forward to working with the Wallaby team to maximize the uptake and impact of the survey within the astronomical community.

Figure 6. Participants of the ASKAP spectral line busy-week at ICRAR/UWA in November 2018

UP-COMING MEETINGS

2019 Feb 11 – 13

12th PHISCC meeting,
University of Western Australia, Australia

2019 Feb 13 – 15

12th PHISCC focus sessions
ICRAR/UWA, Australia

2019 March 18 – 22

The life and death of star-forming galaxies
Scarborough, Australia

2019 July 29 – Aug 23

Galaxy evolution in a new era of HI surveys (MIAPP)
Munich, Germany

REPORT FROM RECENT MEETINGS

WALLABY BUSY-WEEK AT CSIRO ASTRONOMY & SPACE SCIENCE, MARSFIELD (21 – 25 MAY 2018)

by Ahmed Elagali & Tristan Reynolds

This busy week had a strong focus on paper writing, with detailed plans of the topics of everyone's planned papers and dedicated writing on the first few papers in the WALLABY early science series. This was helped in part to ironing out various data processing bugs and issues since the previous busy week, such as Dane solving the main imaging issue of the significant residual sidelobes present in the final image cubes. We also determined the data products that would be useful to be kept and put on CASDA when the processing of the full early science fields is carried out by the ASKAP operators.

ASKAP SPECTRAL LINE BUSY-WEEK AT ICRAR/UWA, CRAWLEY (19 – 23 NOVEMBER 2018)

by Ivy Wong

This busy week had a strong focus on data validation and pipeline verification. As ASKAP begins correlated observations with 28 antennae, much of the responsibility for data processing has reverted back onto the ASKAP operations team. Therefore, this week is spent examining and characterising the data products that have been processed thus far. Figure 6 shows a photo of the participants of this busy-week on the first day of the busyweek. Unfortunately Bi-Qing For (working lead for spectral line data validation metrics) was not able to join us this week as she is representing the AT users at the Australia Telescope Users Committee meeting in Sydney.

WALLABY PUBLICATIONS

2018 articles which mention WALLABY (according to ADS Beta):

Saintonge, A., Wilson, C., Xiao, T. et al 2018 JINGLE, a JCMT legacy survey of dust and gas for galaxy evolution studies - I. Survey overview and first results Monthly Notices of the Royal Astronomical Society, 481, 3497

Shah, M., Bekki, K. Vinsen, K. & Foster, S. 2018 Impact of dark matter sub-halos on the outer gaseous disks of galaxies Monthly Notices of the Royal Astronomical Society, in press

Kraan-Korteweg, R.C., van Driel, W., Schroeder, A.C., Ramatsoku, M. & Henning, P.A. 2018 The Nançay H I Zone of Avoidance survey of 2MASS bright galaxies Monthly Notices of the Royal Astronomical Society, 481, 1262

Patra, N.N. 2018 A self-consistent hydrostatic mass modelling of pressure-supported dwarf galaxy Leo T Monthly Notices of the Royal Astronomical Society, 480, 4369

Reynolds, T.N., Westmeier, T., Staveley-Smith, L., Elagali, A. et al 2018 WALLABY Early Science - I. The NGC 7162 Galaxy Group Monthly Notices of the Royal Astronomical Society, Monthly Notices of the Royal Astronomical Society, in press

Feix, M. 2018 Probing cosmic velocity-density correlations with galaxy luminosity modulations Monthly Notices of the Royal Astronomical Society, 480, 90

Rafieferantsoa, M., Andrianomena, S. & Davé, R. 2018 Predicting the neutral hydrogen content of galaxies from optical data using machine learning Monthly Notices of the Royal Astronomical Society, 479, 4509

Wang, J., Zheng, Z., D'Souza, R., Mo, H., Józsa, G., Li, C., Kamphuis, P., Catinella, B. et al 2018 The prevalence of type III disc breaks in H I-rich and low-spin galaxies Monthly Notices of the Royal Astronomical Society, 479, 4292

Aparicio Resco, M. & Maroto, A.L. 2018 Parametrizing modified gravities with vector degrees of freedom: anisotropic growth and lensing Journal of Cosmology and Astroparticle Physics 10, 014

Parkash, V., Brown, M.J.I., Jarrett, T.H. & Bonne, N.J. 2018 Relationships between HI Gas Mass, Stellar Mass, and the Star Formation Rate of HICAT+WISE (H I-WISE) Galaxies Astrophysical Journal 864, 40

Bekki, K. 2018 Constraining the three-dimensional orbits of galaxies under ram pressure stripping with convolutional neural networks Monthly Notices of the Royal Astronomical Society, in press

Koribalski, B.S., Wang, J., Kamphuis, P., Westmeier, T., Staveley-Smith, L., Oh, S.-H. et al 2018 The Local Volume H I Survey (LVHIS) Monthly Notices of the Royal Astronomical Society, 478, 1611

Qin, F., Howlett, C., Staveley-Smith, L. & Hong, T. 2018 Bulk flow in the combined 2MTF and 6dFGSv surveys Monthly Notices of the Royal Astronomical Society, 477, 5150

Jones, M.G., Haynes, M.P., Giovanelli, R. & Moorman, C. 2018 The ALFALFA H I mass function: a dichotomy in the low-mass slope and a locally suppressed `knee' mass Monthly Notices of the Royal Astronomical Society, 477, 2

Hellwing, W.A., Bilicki, M. & Libeskind, N.I. 2018 Uneven flows: On cosmic bulk flows, local observers, and gravity Physics Review D, 97, 103519

Oh, S.-H., Staveley-Smith, L., Spekkens, K., Kamphuis, P. & Koribalski, B.S. 2018 2D Bayesian automated tilted-ring fitting of disc galaxies in large H I galaxy surveys: 2DBAT Monthly Notices of the Royal Astronomical Society, 473, 3256

Stark, D.V., Bundy, K.A., Orr, M.E., Hopkins, P.F., Westfall, K., Bershady, M., Li, C., Bizyaev, D. et al 2018 SDSS-IV MaNGA: constraints on the conditions for star formation in galaxy discs Monthly Notices of the Royal Astronomical Society, 474, 2323

Schneider, A. & Truijillo-Gomez, S., 2018 Constraining cosmology with the velocity function of low-mass galaxies Monthly Notices of the Royal Astronomical Society, 475, 4809

Elahi, P.J., Welker, C., Power, C., Lagos, C.D.P., Robotham, A.S.G., Cañas, R. & Poultoun,R. 2018 SURFS: Riding the waves with Synthetic UniveRses For Surveys Monthly Notices of the Royal Astronomical Society, 475, 5338