32nd URSI GASS, Montreal, 19–26 August 2017

Early Science results from ASKAP

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Abstract

ASKAP has recently started its Early Science program with 12 MkII PAF-equipped antennas and 36 beams simultaneously covering a 30 square degree field of view. The first observations have focused on mapping extragalactic neutral hydrogen in galaxy groups and clusters selected by the 'WALLABY' Survey Science Team. Significant efforts from engineers, software designers, and scientists are overcoming obstacles and paving the way to most effectively utilized the new hardware and software developed for ASKAP. Preliminary results are quite promising and indicate a very successful scientific future for ASKAP.

1 Introduction

Since the discovery of a radio source in the centre of the Milky Way by Karl Jansky and the subsequent construction of the first radio telescope for astronomical research by Grote Reber in 1930s, radio frequency observatories have been surveying the sky to answer fundamental questions about the Universe. Modern radio telescopes are becoming more capable of looking deeper into space, having wider fields of view, detecting more sources, and resolving details about celestial objects near and far. The continual push forward to understand our cosmic origin and the potential for new discoveries has drawn global support for the Square Kilometre Array (SKA) and its precursor telescopes.

2 ASKAP

The Australian Square Kilometre Array Pathfinder (ASKAP) uses state-of-the-art technology to carry out wide-field observations with unprecedented survey speed, sensitivity, and resolution. This radio interferometer consists of 36 $\times$ 12-m antennas, has a total collecting area of approximately 4,000 square metres, covers a frequency range from 700 MHz to 1.8 GHz with 300 MHz of instantaneous bandwidth, and is equipped with MkII Phased Array Feeds (PAFs) that yield a 30 square degree field of view [1]. The tremendous amount of data ($\sim$2.5 GB per second or 75 PB per year) that will be produced by ASKAP is a significant technical challenge for current computing and archiving abilities. The ASKAP Science Data Processor software, ASKAPsoft, is an automated pipeline running on the Pawsey Supercomputing system that has been specifically designed to reduce, calibrate, image, and analyze ASKAP observations [2, 3]. Ongoing efforts from engineers, software designers, and scientists are continuously developing and improving the hardware and software capabilities of ASKAP.

Numerous key science projects have been planned for this wide-field radio frequency survey instrument. Once fully operational, ASKAP will make substantial scientific advances in these key areas:

- galaxy formation and gas evolution in the nearby Universe through wide and deep extragalactic neutral hydrogen (HI) surveys
- evolution, formation, and population of galaxies across cosmic time via high resolution radio continuum surveys
- characterization of the radio transient sky through detection and monitoring (including Very Long Baseline Interferometry) of transient and variable sources, and
- evolution of magnetic fields in galaxies over cosmic time through polarization surveys.

3 WALLABY: the ASKAP HI All-sky Survey

The Wide-field ASKAP L-Band Legacy All-sky Blind surveY (WALLABY; PIs B. Koribalski & L. Staveley-Smith) will cover 75% of the sky and is predicted to detect HI in more than 500,000 galaxies out to a redshift of 0.26 [1, 4]. This survey has been designed to study the HI properties, environments and large-scale distribution of gas-rich galaxies. The large extent and homogeneity of WALLABY will enable detailed examination of galaxy formation and evolution, the role of galaxy mergers and interaction events, the HI mass function and its relation with galaxy density, the physical processes governing cool gas at low redshift, cosmological parameters relating to gas-rich galaxies, and the nature of the cosmic web – making it an important pathfinder for key SKA science.

With 36 fully functional ASKAP antennas, WALLABY will take 2-3 years of integration time (divided over $\sim$1300 fields) to cover a declination range of $-90^\circ < \delta < +30^\circ$ with an angular resolution of 30 arcsec and a spectral resolution of 4 km s^{-1}. The expected survey RMS of 1.6 mJy beam^{-1} per channel will provide sufficient sensitivity to detect low-mass dwarf galaxies (with an HI mass of M_{H_I} = 10^8 $M_\odot$) out to a distance of ∼60 Mpc and super-massive galaxies (HI mass = 10^{10} $M_\odot$) out to the survey 'edge' at 1 Gpc away [5]. The significant data volume and large number of HI sources will require automated 3D source finding algorithms – such as SoFiA [6] – to detect, extract, and fully characterize galaxies and other gas-rich features in the ASKAP datacubes [7, 8].

4 ASKAP Early Science

ASKAP Early Science is an observing program aimed at producing scientifically useful data, with at least 12 MkII PAF-equipped ASKAP antennas (i.e. ASKAP-12), while commissioning ASKAP to full specification [9]. The priorities for this program are to demonstrate the unique capabilities of ASKAP, produce data sets to facilitate the development of data processing and analysis techniques, and achieve high scientific impact. It is estimated that completing the commissioning of the full ASKAP array will take at least one year after the commencement of Early Science. During that period, ∼20% of the available telescope time (i.e. 1800 hours) will be available for science observations. WALLABY has been allocated 800 hrs of Early Science observing time, which will be used to observe 5-7 fields – with various integration times dependent on the properties and configuration of ASKAP – at the full WALLABY sensitivity and resolution.

After successful commissioning observations in August, we produced detailed HI maps of the spiral galaxy, IC 5201 (Figure 1), in October 2016, ASKAP officially started its Early Science program with observations for WALLABY. Over the past few months, four different extragalactic WALLABY Early Science fields have been observed using ASKAP-12 (see Table 1). The over 400 hours of HI data has not only tested the current capabilities of the array hardware, but have also challenged all aspects of queued scheduling (with remote operations using the ASKAP Observation Management Portal), data transfer and storage (using the Pawsey Supercomputing Centre), data processing and analysis with ASKAPsoft, and eventual archiving and public released through the newly developed CSIRO ASKAP Science Data Archive (CASDA) system. Thus far, significant progress has been made towards developing the automated software required to run ASKAP and produce science-worthy results, as showing in Figure 2.

Table 1. WALLABY fields that have been observed during the ASKAP Early Science program

Field identifier	Bandwidth (MHz)	Time on source (hours)
NGC 7232 group	48	140
Fornax cluster	192	160
Dorado group	192	70
M83 field	192	80

5 Conclusions and Future Work

ASKAP has officially started its Early Science program. In between hardware installation, maintenance, and commissioning tests, ASKAP is streaming in science-worthy observations. Although we are currently using 1/3 of the full array and only a portion of the bandwidth, the volume of the data has already proved to be rather challenging. Through 'trial and error' as well as a very collaborative effort from everyone involved in the ASKAP project, we are consistently improving the capabilities of ASKAP. In addition to expanding the array to include more antennas and cover a larger bandwidth, there are still several features in the data processing software that require further development (e.g. calibration methods, combining multi-epoch data, continuum subtraction for the spectral line cubes) over the next several months. Nevertheless, ASKAP is currently showing great promise and is definitely paving the way for the SKA.

6 Acknowledgements

The Australian SKA Pathfinder is part of the Australia Telescope National Facility which is managed by CSIRO. Operation of ASKAP is funded by the Australian Government with support from the National Collaborative Research Infrastructure Strategy. ASKAP uses the resources of the Pawsey Supercomputing Centre. Establishment of ASKAP, the Murchison Radio-astronomy Observatory and the Pawsey Supercomputing Centre are initiatives of the Australian Government, with support from the Government of Western Australia and the Science and Industry Endowment Fund. We acknowledge the Wajarri Yamatji people as the traditional owners of the Observatory site.

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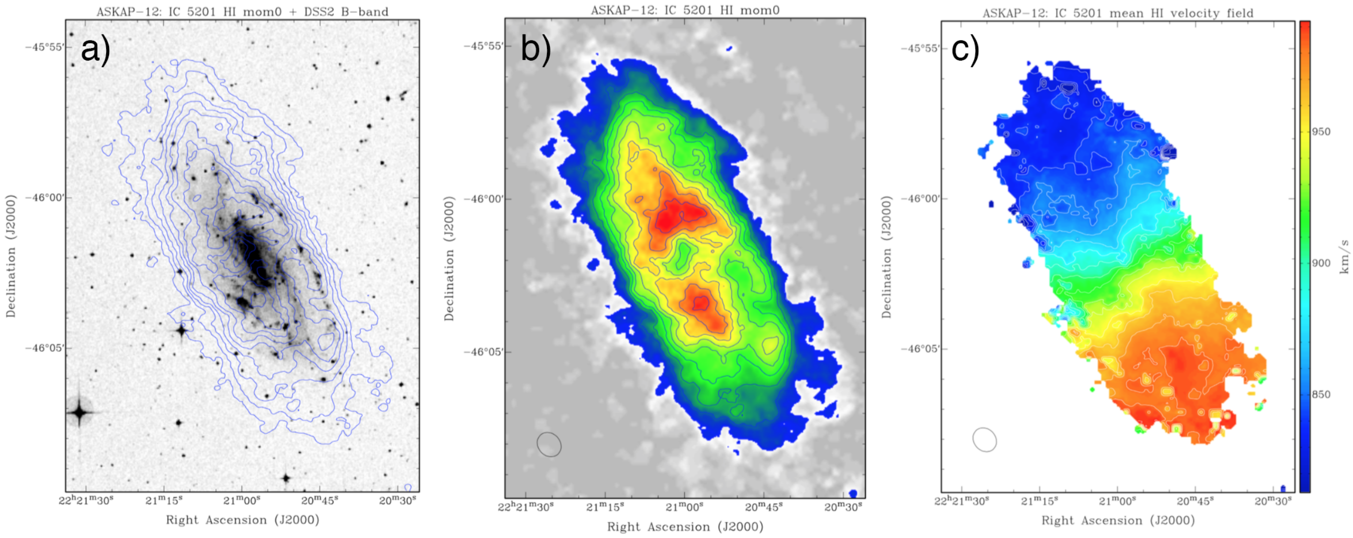

Figure 1. ASKAP-12 HI maps of the galaxy IC 5201, observed on 12 Aug 2016. a) total intensity HI contours (in blue) superimposed on a DSS2 optical image. The gas clearly extends beyond the extend of the stars in the galaxy; b) total intensity HI map; c) HI velocity field. The ∼12 hours of commissioning observations have a bandwidth of 48 MHz, and a resolution of ∼50 arcsec and 4 km s^{-1}. (Image credit: ASKAP Spectral Line Data Processing working group and ASKAP Computing team)

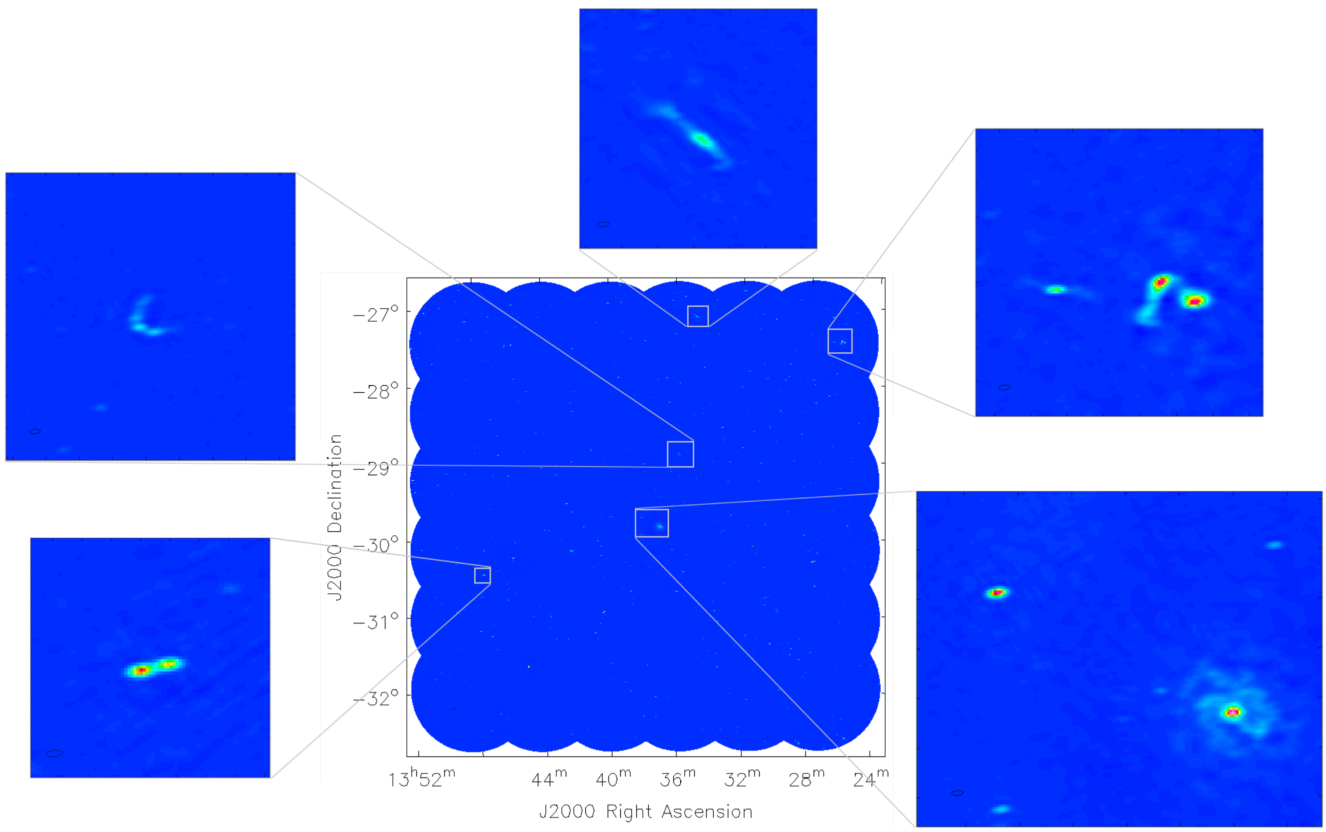

Figure 2. ASKAP ES continuum map of the region around M83, observed on 31 Dec 2016 and processed using ASKAPsoft. The central map shows the fully mosaicked 30 square degree field of view that was simultaneously observed with 36 beams. The outer boxes highlight some of the features detectable after ∼10 hours of observations using 10 ASKAP antennas (that were working at that time), 192 MHz bandwidth, and a 42 × 17 arcsec synthesized beam. The level of sensitivity and distinguishable details in these maps hint at the science potential for ASKAP.

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