An update on ASKAP and WALLABY

The ASKAP HI All-Sky Survey

Bärbel Koribalski
Six of the 36 ASKAP dishes

The Australian SKA Pathfinder

• **ASKAP**: 36 × 12-m dishes equipped with *phased array feeds* (PAFs) delivering 30 sq degr field of view (freq 0.7 – 1.8 GHz, baselines up to 6 km) \(\Rightarrow\) ASKAP is a 21-cm survey machine!

• ASKAP’s **data rate** is expected to be **72 Tbit/s** (once fully operational), data output \(\sim 500\;\text{PB} /\text{yr}\); raw data will be stored only temporarily; archive data outputs (images/cubes) long term

• **ASKAP correlator** (delivering **340 Tflop/s**
Apr 2014:
six PAFs on ASKAP
working together

Phased Array Feed Mk I

FOV = 30 sq degrees
• **WALLABY** (Koribalski/Staveley-Smith) All sky HI survey to $z \sim 0.2$
• **EMU** (Norris) All sky continuum to 10 $\mu$Jy rms

• **POSSUM** (Gaensler/Landecker/Taylor) Polarization / RM grid
• **FLASH** (Sadler) HI absorption to $z \sim 1$
• **VAST** (Murphy/Chatterjee) Transients and variables (>5 sec)
• **CRAFT** (Dodson/Macquart) Fast transients (<5 sec)
• **GASKAP** (Dickey) Galactic and Magellanic HI and OH
• **DINGO** (Meyer) Deep HI emission survey

• **COAST** (Stairs) Pulsar timing and searching
• **VLBI** (Tingay) ASKAP as part of the LBA

• 25% of ASKAP time for other projects (ATNF TAC)
ASKAP Survey Science Projects

• WALLABY (Koribalski/Staveley-Smith) All sky HI survey to $z \sim 0.2$
• EMU (Norris) All sky continuum to 10 $\mu$Jy rms
• POSSUM (Gaensler/Landecker/Taylor) Polarization / RM grid

Large-area (Dec < 30°) 
ASKAP 21-cm survey delivers all three!

About one year, 
~1300 pointings
ASKAP HI All-Sky Survey

WALLABY PIs: Bärbel Koribalski & Lister Staveley-Smith

WALLABY overview paper (Koribalski et al, 2014, in prep.) * Figure by Tobias Westmeier.
The M81 / M82 galaxy group

(Yun et al. 1993)
ASKAP: 36 × 12-m antennas. (Picture credit: Simon Johnston)

WALLABY + WNSHS (Koribalski 2012)

- ASKAP H\(\text{\textasciitilde}\) All-Sky Survey (\(\delta < +30^\circ\))
- Westerbork Northern Sky H\(\text{\textasciitilde}\) Survey (\(\delta > +27^\circ\))
ASKAP: 36 antennas assembled.
(Picture credit: Simon Johnston)

WALLABY parameters:

- **survey time:** ~ one year
- **sky coverage:** $-90^\circ < \delta < +30^\circ$ (max. $+50^\circ$)
  
  \[
  \text{FOV} = 30 \text{ sq deg (i.e. } 400 \times \text{ ATCA primary beam)}
  \]
- **velocity coverage:** $-2,000$ to $77,000$ km/s ($z = 0.26$)
  
  \[
  \text{BW} = 300 \text{ MHz divided into 16,384 channels}
  \]
- **resolution:** 30", 4 km/s (+ 10" postage stamps)
- **integration time:** 8 (12) hours per pointing
- **line sensitivity:** $\sim 1.5$ (1.3) mJy/beam per channel
- **330 TB total storage for Stokes-I cubes**
WALLABY science goals:

We will examine the HI properties and large-scale distribution of \( \sim 600,000 \) galaxies out to \( z = 0.26 \) and study, for example:

- their gas content as a function of environment
- their disk kinematics and dark matter distribution
- signatures of gas accretion and ram pressure stripping
- the HI mass function and its variation with galaxy density
- large-scale structures of galaxies, bulk flow motions
WALLABY will explore

- the *Gaseous* Universe
- the *Dynamic* Universe
- the *3D* Universe
- the *Dark* Universe

and

- the *Unknown* Universe
... probing the Gaseous Universe

WALLABY will discover

- new dwarf galaxies in the Local Group
- hundreds of dwarfs in the Local Volume (5 x 10⁶ M☉ out to 10 Mpc)
- diffuse HI clouds, tails and filaments connecting galaxies
- 10⁸ M☉ out to 60 Mpc

VLA HI + Spitzer MIR + Galex UV; Walter et al. (2009)
... probing the Gaseous Universe

WALLABY will reveal

- the large-scale HI disks of spiral galaxies
- HI streams in galaxy haloes resulting from the accretion of neighbouring dwarf galaxies
probing the Gaseous Universe

NGC 3263 group – English, BK et al. (2010)

WALLABY will discover

- tidal tails and HI plumes as the signatures of interacting galaxies
- distant high-density HI clouds and filaments, most likely in groups & clusters

... explore **the Dynamic Universe**

**WALLABY** will reveal

- the large-scale HI velocity fields of spiral galaxies
- disk rotation ("spider diagram")
- gas outflow/infall
- polar rings, accretion, etc.

The starburst galaxy NGC 253

Dennison Mural @ U Michigan, IYA2009:
*The Universe – Yours to Discover*
explore the Dynamic Universe

**IC 4662** (van Eymeren, BK et al. 2009)

**LVHIS** galaxies (gas + stars)

**NGC 5253** (Lopez-Sanchez, BK et al. 2010)
... uncover the Dark Universe

LVHIS: Kirby, BK et al. (2010)

HIZOA J0836-43 $v_{rot} = 300$ km/s

THINGS: Walter et al. (2009)

$M_{dyn} = 2.31 \times 10^5 R_{kpc} v_{rot}^2$
... exploring the 3D Universe

ASKAP uv-coverage: 30 / 36 antennas

10.0klambda

HIPASS supercube made by Russell Jurek, 3D visualisation by Amr Hassan & Chris Fluke

Archive

1200 × ASKAP HI cube

Baerbel Koribalski * SkyMapper workshop
ATCA HI maps for HIPASS J0615-57 at $D_{\text{TRGB}} = 6.05$ Mpc

$M_{\text{HI}} = 2.6 \times 10^7 M_\odot$ (ESO121-G020) $+ M_{\text{HI}} = 6.1 \times 10^6 M_\odot$ (companion) (Warren et al. 2004)
Each HI spectrum provides:

- the galaxy redshift ($v_{\text{sys}}$),
- rotation velocity ($v_{\text{rot}}$),
- HI mass, and
- total dynamical mass.
WALLABY redshift range: $z = 0$ to $0.26$
SoFiA - our new Source Finding Application

developed by members of the WALLABY source finding working group (TWG4)
Tobias Westmeier, Paolo Serra, Nadine Giese, Russell Jurek, Lars Flöer, Attila Popping and Benjamin Winkel

* SoFiA Handbook (on-line)

Can you spot the dwarf galaxy Leo T?
Can you spot the dwarf galaxy Leo T?
WALLABY and SkyMapper Science

• **WALLABY** will detect ~ **600 000 galaxies** in HI (z < 0.25)
  • HI positions (accurate astrometry; uncertainty <10")
  • HI systemic velocity (accurate to a few km/s)
  • HI velocity width ➞ rotational velocity

• **Optical identifications**
  • nearby dwarf galaxies
  • star-forming spiral galaxies
  • tidal tails, plumes and clouds

• **Galaxy properties: optical and HI**
  • disk major and minor diameters
  • *accurate inclination angles* ➞ TFR, total dynamical mass
Tully-Fisher Relation – Bulk Flow Field

Key Science for WALLABY

HIPASS Tully-Fisher relation (Meyer et al. 2008)

Local Universe flow field (Hudson/EFAR/SMAC)
The Busy Function:  
a new analytic function for describing the integrated 21-cm spectral profile of galaxies


WALLABY and SkyMapper Science

- **SkyMapper Galaxy Survey**
  - galaxy morphologies (disk/bulge decomposition)
  - galaxy colours

- **TAIPAN Galaxy Redshift Survey**
  - many galaxies undetected in HI
  - HI spectral stacking

- **HI – optical scaling relations**
  - diameters, magnitudes

- **SkyMapper deep fields at 5” seeing?**
  - nearby galaxies, pairs and groups
  - image the faint outer disk
  - search for stars in HI tidal tails

Baerbel Koribalski * SkyMapper workshop
The Antennae
Merging Galaxy Pair NGC4038/9
Gordon, Koribalski et al. 2003

ATCA HI image
DSS image
GALEX image
HIPASS J0739-69: NGC2442 + intra-group HI gas
(Ryder, Koribalski et al. 2001)

- $10^9 M_\odot$ intra-group HI gas
- 250 kpc projected separation from the galaxy NGC 2442
- no optical counterpart
- resolved into numerous clumps with the ATCA

NGC 2442 UKS/DSS

HIPASS BGC

Right Ascension (J2000)

Declination (J2000)
HCG 44

Sloan Digital Sky Survey (SDSS) optical colour image of HCG 44 (Data Release 8).

Serra, Koribalski, Duc et al. 2013, MNRAS 428, 370

Baerbel Koribalski * SkyMapper workshop
HCG 44

Constant-column-density HI contours overlaid on the g-band CFHT/MegaCam image.

Serra, Koribalski, Duc et al. 2013, MNRAS 428, 370
Koribalski et al. 2014, in prep.

(by Bob Franke)

Baerbel Koribalski * SkyMapper workshop
ASKAP Commissioning

BETA = Boolardy Engineering Test Array (six antennas)
BETA Mk1 PAFs – an engineering testbed

HIPASS 20-cm radio continuum map

3 & 9 beam continuum images achieved with 3 PAFs

HIPASS 20-cm radio continuum map

Parkes multibeam

BW = 16 x 1 MHz
12h, 1p, 928 MHz

9 beams

BW = 32 x 1 MHz
12h, 1p, hardware corr.

3 beams

BW = 64 MHz (1024 ch)
8 min/pointing, 2 pols
15.5 arcmin resolution
First 9-beam image with six PAFs on ASKAP antennas

- 6 antennas (36)
- 2 x 3 baselines (630)
- 9 beams (36)
- 304 MHz bandwidth ✓

Feb 2014

here: 304 x 1 MHz channels
First BETA results: 15 baselines working!
BETA = 6 Mk1 PAFs working together
producing 9-beam continuum maps + HI images/spectra for science verification

The starburst galaxy **NGC 253** is a member of the Sculptor Group. It has ~6 Jy radio continuum flux at 20-cm; very bright HI emission (and absorption) over 400 km/s, approx. from 1418 - 1420 MHz.
ASKAP Commissioning – Part 2

with Mk II PAFs or ADE PAFs
ASKAP Mk II Phased Array Feed (PAF) assembly
- 94 dominos (each dual pol.)
- 188 checkerboard elements

→ 36 beams (each FWHM ~1.2°)
→ 30 sq deg field-of-view (FOV)
or 36 individual fields
or large FOV + steered beams
• 94 dominos (each dual polarisation)
• 188 checkerboard elements
• 36 beams
  combined to give FOV = 30 sq deg
• or 36 individual fields
• or large field + nulling of RFI

ASKAP Mk II Phased Array Feed (PAF) assembly

PAF Mk II checkerboard (low Tsys across band) and composite casing, providing RFI and weather shielding.

System performance

Tsys < 50 K

Bandwidth = 300 MHz

0.7

HI survey

1.8
ASKAP Mk II Phased Array Feed (PAF) assembly

later in 2014: PAF Mk II system installation

ASKAP
36 x 12-m dishes
baselines ≤ 6 km
Hydrogen as a tracer of tidal interactions
(Putman et al. 1998)

HI Early Science with ASKAP-12

Bärbel Koribalski
Target ~10 fields
≥ 60 h each

**Umbrella Theme:**
Galaxy evolution as a function of environment.

How do physical processes affect the HI morphology and kinematics of galaxies in voids, groups & clusters.
Six MkII PAFs working together could produce this:

Atomic Hydrogen in the LMC (Kim et al. 1998)

Infrared Portrait of the LMC (Spitzer + Herschel)

Large field-of-view demonstrator science.
Groups & Cluster are excellent targets to study the physical processes that disrupt and transform galaxies in a medium to high density environment. Galaxy HI morphologies and kinematics are strongly affected.

**VLA HI Study of the Virgo Cluster.**

About **400h** to obtain single pointings of 53 late-type Virgo cluster galaxies.

SDSS + HI contours (Chung et al. 2009).
The 21-cm spectral line allows us to study

- the physical processes affecting galaxy disks
- star-formation locations in the outer disk
- gaseous filaments/bridges between galaxies
- intra-group/cluster gas
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Using HI maps to determine the morphology of HI deficient and HI excess galaxies:

HI stripping and HI accretion methods in spiral galaxies

*slide by Virginia Kilborn*
BETA / ASKAP Early Science Fields

ASKAP-ADE
6 – 12+ dishes

PAF field-of-view (30 sq deg)

Circinus field: isolated nearby galaxy
ASKAP-ADE
6 – 12+ dishes

PAF field-of-view (30 sq deg)

Fornax field: a nearby galaxy cluster
WALLABY – the ASKAP HI / 21-cm All-Sky Survey

~1200 fields ($t_{\text{int}}$~ 8h) each 30 sq

Estimated detections per field:
- 500 HI galaxies
- 70 000 continuum sources
- 0.5 HI absorbers
- many transients

36 beams
http://www.atnf.csiro.au/research/WALLABY

Dr. Bärbel Koribalski
CSIRO Astronomy and Space Science
Australia Telescope National Facility
SkyMapper workshop – 8 Apr 2014
The Galaxy M83

(Koribalski et al., in prep.)

HIPASS J1336–29
D \approx 4.5 \text{ Mpc}
HI extent \text{ > 80 kpc}
M_{\text{HI}} = 8 \times 10^9 \text{ } M_\odot

HI is an excellent tracer for SF in the outer disk