ASKAP
and EMU
Andrew Hopkins
Australian Astronomical Observatory
ASKAP and EMU

Evolutionary Map of the Universe

Andrew Hopkins
Australian Astronomical Observatory
**ASKAP**

- *Australian SKA Pathfinder*, completed late 2013, 36×12m antennas
- Antennas have a 100-pixel phased array feed (PAF), giving a 30 square degree FOV
- Being built in Murchison Shire, Western Australia
- All 36 dishes are already deployed
- 18 PAFs are funded, 6 already deployed
- BETA (Boolardy Engineering Test Array) now taking data
Australian SKA Pathfinder, completed late 2013, 36 × 12m antennas. Antennas have a 100-pixel phased array feed (PAF), giving a 30 square degree FOV. Being built in Murchison Shire, Western Australia. 18 PAFs are funded, 6 already deployed. BET A (Boolardy Engineering Test Array) now taking data. Image credit: Lisa Harvey-Smith.
ASKAP
ASKAP

Gazetted towns: 0
Population: “up to 160”
ASKAP PAF

Credit: Lisa Harvey-Smith
ASKAP surveys

- EMU - radio continuum survey
- WALLABY - HI “all-sky” survey
- POSSUM - polarisation survey
- DINGO - deep HI survey, covering the GAMA regions
- VAST - variable/transient survey
- FLASH - HI absorption survey
**ASKAP surveys**

- **EMU** - radio continuum survey
- **WALLABY** - HI “all-sky” survey
- **POSSUM** - polarisation survey
- **DINGO** - deep HI survey, covering the GAMA regions
- **VAST** - variable/transient survey
- **FLASH** - HI absorption survey
ASKAP surveys

- **EMU** - radio continuum survey
- **WALLABY** - HI “all-sky” survey
- **POSSUM** - polarisation survey
- **DINGO** - deep HI survey, covering the GAMA regions
- **VAST** - variable/transient survey
- **FLASH** - HI absorption survey
ASKAP surveys

- **EMU** - radio continuum survey
- **WALLABY** - HI "all sky" survey
- **POSSUM** - polarisation survey
- **DINGO** - deep HI survey, covering the GAMA regions
- **VAST** - variable/transient survey
- **FLASH** - HI absorption survey
ASKAP surveys

- **EMU** - radio continuum survey
- **WALLABY** - HI "all sky" survey
- **POSSUM** - polarisation survey
- **DINGO** - deep HI survey, covering the GAMA regions
- **VAST** - variable/transient survey
- **FLASH** - HI absorption survey
ASKAP surveys

- **EMU** - radio continuum survey
- **WALLABY** - HI "wallaby" survey, covering the GAMA regions
- **POSSUM** - polarisation survey
- **DINGO** - deep HI survey
- **VAST** - variable/transient survey
- **FLASH** - HI absorption survey
ASKAP surveys:

- **EMU** - radio continuum survey
- **WALLABY** - HI "wall-by" survey
- **POSSUM** - polarisation survey
- **DINGO** - deep HI survey, covering the GAMA regions
- **VAST** - variable/transient survey
- **FLASH** - HI absorption survey
EMU Survey

- "All sky south of +30° declination."
- "Synthesized beam width: 10” FWHM"
- "Frequency range: 1100-1400 MHz"
- "RMS noise: 10 μJy"
- "Total integration time: ~1.5 yrs (12 hr per field)"
- "~70 million sources"
EMU Survey
EMU Survey
EMU team

- **Project leader:** Ray Norris
- **Project scientists:**
  - Andrew Hopkins
  - Nick Seymour

- >220 members from 17 countries
- Split into ~15 working groups
- Cross-linkages with other major multi-wavelength surveys

### Radio
- LOFAR
- WSRT+Apertif/WODAN
- NVSS
- SUMSS
- MWA
- ATLAS
- SPT
- GMRT

### Optical/IR
- SDSS
- LSST
- Pan-STARRS
- 2MASS
- HLA
- VISTA/VIKING/VHS/VIDEO
- GAMA
- VST/KIDS
- UKIDSS
- Herschel ATLAS/HERMES
- WISE
- SkyMapper
- TAIPAN
ASKAP vs PDS

ASKAP Simulation
Phoenix Deep Survey
How did galaxies form and evolve?
How did galaxies form and evolve?

- Evolution of star formation over the past 10 Gyr ($z<2$)
  - using a wavelength unbiased by dust or molecular emission.

- Evolution of massive black holes
  - and understanding their relationship to star formation.

- Explore the large scale structure and cosmological parameters of the universe
  - including an independent measure of dark energy evolution.

- Explore an uncharted region of observational parameter space
  - almost certainly finding new classes of object.
Additional goals

- Explore diffuse low surface brightness objects
- Generate an atlas of the Galactic Plane
  - star formation
  - supernovae
  - pulsars
  - Galactic structure
- Legacy value
  - Herschel
  - JWST
  - ALMA
  - ESO public surveys
1.4GHz Source Counts
1.4GHz Source Counts

- Windhorst 1993 compilation
- HDFN (Biggs)
- Lockman Hole (Biggs)
- COSMOS (Bondi)
- HDFS (Huynh)
- PDF Primary (Hopkins)
- PDF Deep (Hopkins)
- 13hr XMM deep (Seymour)
- SXDF (Simpson)
- ATESP (Prandoni)
- FIRST (White)
- Marano (Groppioni)
- 1046 (Owen)
- SSA13 (Fomalont)
- CDFS (Kellermann)
1.4GHz Source Counts

![Graph showing 1.4GHz source counts with various types of sources such as AGN, SFG, and a total count. The x-axis represents 1.4GHz flux density (mJy), and the y-axis represents the square of the flux density per steradian.](image)
1.4GHz Source Counts

13H XCDF – Seymour et al. 2008
HDFN – Muxlow et al. 2005
SXDF – Simpson et al. 2006
COSMOS – Smolcic et al. 2008
Lockman – Ibar et al. 2009
ECDFS – Padovani et al. 2008
To trace the evolution of the dominant star forming galaxies from $z=5$ to the present day

EMU will detect ~45 million SF galaxies

Milky Way type galaxies to $z=0.3$

M82 types to $z=1$

Arp 220 types to $z=2$
Evolution of Star Formation

Evolution of Star Formation

Evolution of Star Formation

Compare the number of different types of radio AGN as a function of cosmic time (FRI vs FRII, radio-quiet QSO vs radio-loud, etc)

Look for connections between star formation rate and numbers of AGN

Evolution of AGN

- **EMU will detect about 25 million AGN**

- High-z AGN
- Composite AGN/SF galaxies
- Galaxies in a brief transition phase from quasar-mode to radio-mode accretion

20 million extragalactic redshifts to $r<22$ is a good start.

Perhaps 50% of these will be EMU counterparts (based on existing spectroscopy of similarly deep radio surveys).

4MOST can increase spectroscopic completeness of EMU from 1% to ~10%.
**4MOST and others**

- SKA Phase 1 will be built (maybe) by 2019, so well-matched in time to 4MOST.
- LSST will be operational around the same time.
- SKA Phase 1 will be an order of magnitude larger in terms of survey sizes, than ASKAP and other pathfinders.
- Even with 4MOST we will still not be keeping up with the demand for spectroscopic redshifts.
Transforming Astronomical Imaging-surveys through Polychromatic Analysis of Nebulae

Survey with the UK Schmidt Telescope at Siding Spring, following in the footsteps of the 6dF Galaxy Survey (Jones et al., 2004, 2009)

All southern sky multi-object spectroscopic survey, ~0.5 million galaxies, r<~17 (but NIR selected, as with 6dFGS), 3-5 yr survey starting in ~2015.

10-12 December, workshop in Sydney:
The next generation of hemispheric redshift surveys and the prospects for TAIPAN

10-12 Dec 2012, Sydney, Australia

SOC
Prof. Quentin Parker (Chair, MQ/AAO)
Prof. Andrew Hopkins (Co-Chair, AAO)
Prof. Lisa Kewley (ANU)
Prof. John Peacock (Univ. Edinburgo)
Dr. Heath Jones (Monash)
Prof. Bryan Gaensler (Univ. Sydney)

Invited Speakers
Joss Bland-Hawthorn
Simon Driver
Lister Staveley-Smith
Baerbel Koribalski
Matthew Colless
Tom Jarrett
Jon Lawrence
Fred Watson
Florian Beutler
Ray Norris

LOC
Prof. Quentin Parker (MQ/AAO)
Dr. Lee Spitler (MQ/AAO)
Dr. Michelle Cluver (AAO)
Dr. Maritza A. Lara-Lopez (AAO)
Dr. Borja Anguiano (MQ)
Travis Stenborg (MQ)
Amanda Manypeny (MQ)

Major topics: Synergies with ASKAP galaxy surveys, precision cosmology, galaxy evolution, the connection between gas and stars, the impact of environment and mergers, large scale structure, stellar and halo mass functions, star formation and AGN, and the intergalactic magnetic field.

EMU: http://askap.pbwiki.com/
EMU Cosmology

- **Uses the distribution of radio sources to measure the large scale structure and cosmological parameters of the universe**

- **ISW effect, cosmic magnetism, modified gravity**

*Norris et al., 2011, PASA, 28, 215*
Opening up parameter space

New classes of object, such as IFRSs

Diffuse structures

- Determine luminosity function of relics and shocks, and how this evolves with redshift.
- How do bent radio sources depend on environment, and can we use them to detect clustering at high redshift?
- How common are low luminosity radio galaxies?
- Do diffuse structures end at $z \sim 1$ because of inverse Compton cooling? If not, why not?

The Galactic Plane

- **Deeper and higher resolution than existing surveys**
  - CGPS: arcmin, few mJy, 73° of northern plane
  - SGPS: arcmin, 35 mJy, most of southern plane
  - MAGPIS: 6", 1-2 mJy, 27° of northern plane
  - EMU: 10", 50 μJy, most of plane (all when combined with WODAN/APERTIF)

- **Complete census of:**
  - All phases of HII region evolution
  - Most compact and youngest supernova remnants
  - Radio emitting PNe, to constrain Galactic density and formation rate