

A photograph of two large radio telescope dishes in a desert landscape. The dishes are white and mounted on tall, grey, lattice-like structures. They are situated in a dry, red-brown desert with sparse green shrubs and trees. In the background, there are more dishes and a small building under a clear sky.

# Evolutionary Map of the Universe: Overview and Re-acceleration

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**Ray Norris, CSIRO Astronomy & Space Science**

# This talk

**1) Overview**

**2) EMU “re-acceleration”**

**3) How to get involved**

**Total bandwidth = 2.1THz per antenna**



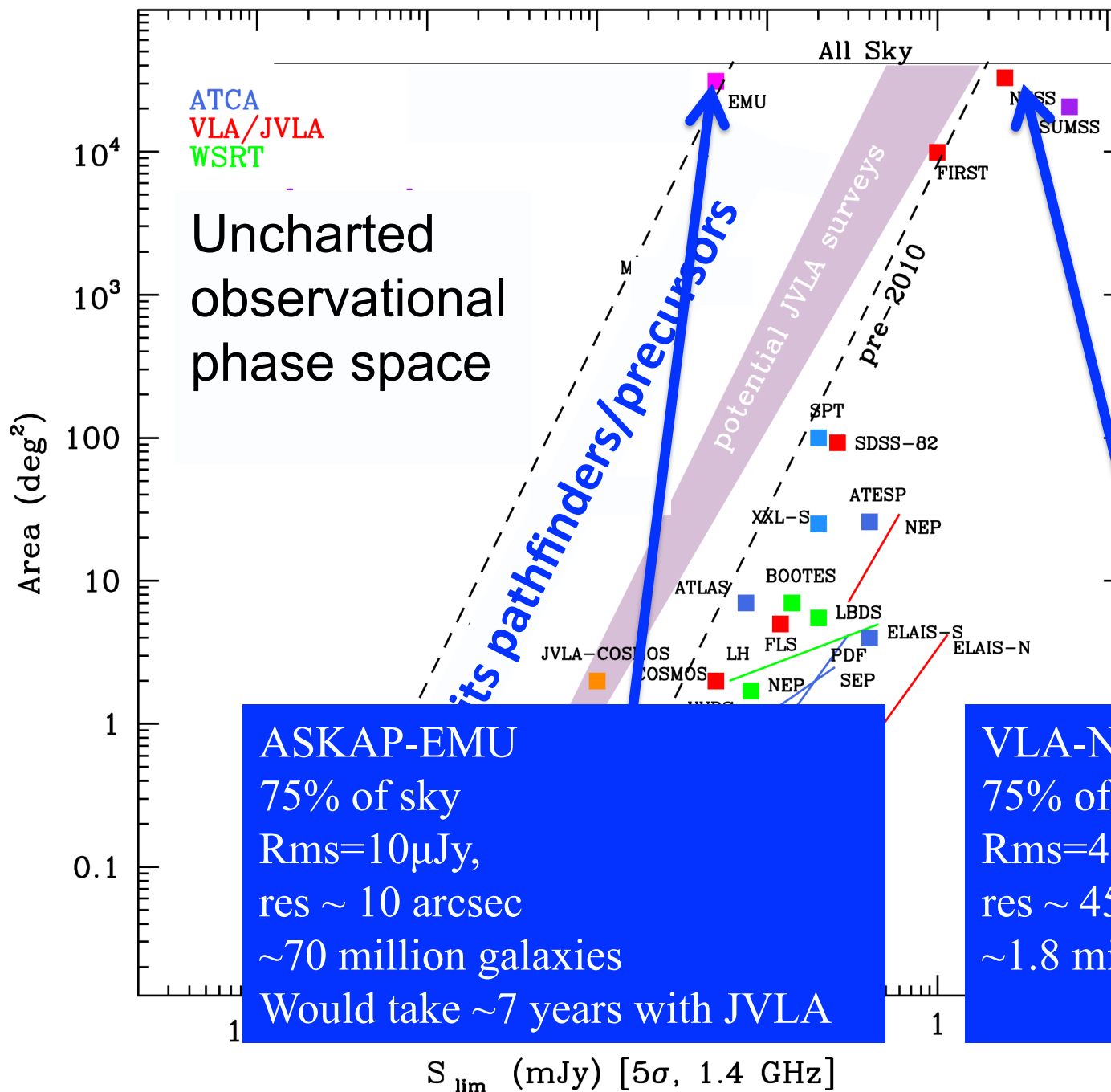


Diagram courtesy of Isabella Prandoni

# Current ASKAP status

- All 36 antennas and infrastructure completed, all funding in place (for 30 PAFs)
- Engineering prototype array (“BETA”) currently operating with prototype PAFs on 6 antennas giving 9 beams
- Construction going amazingly well

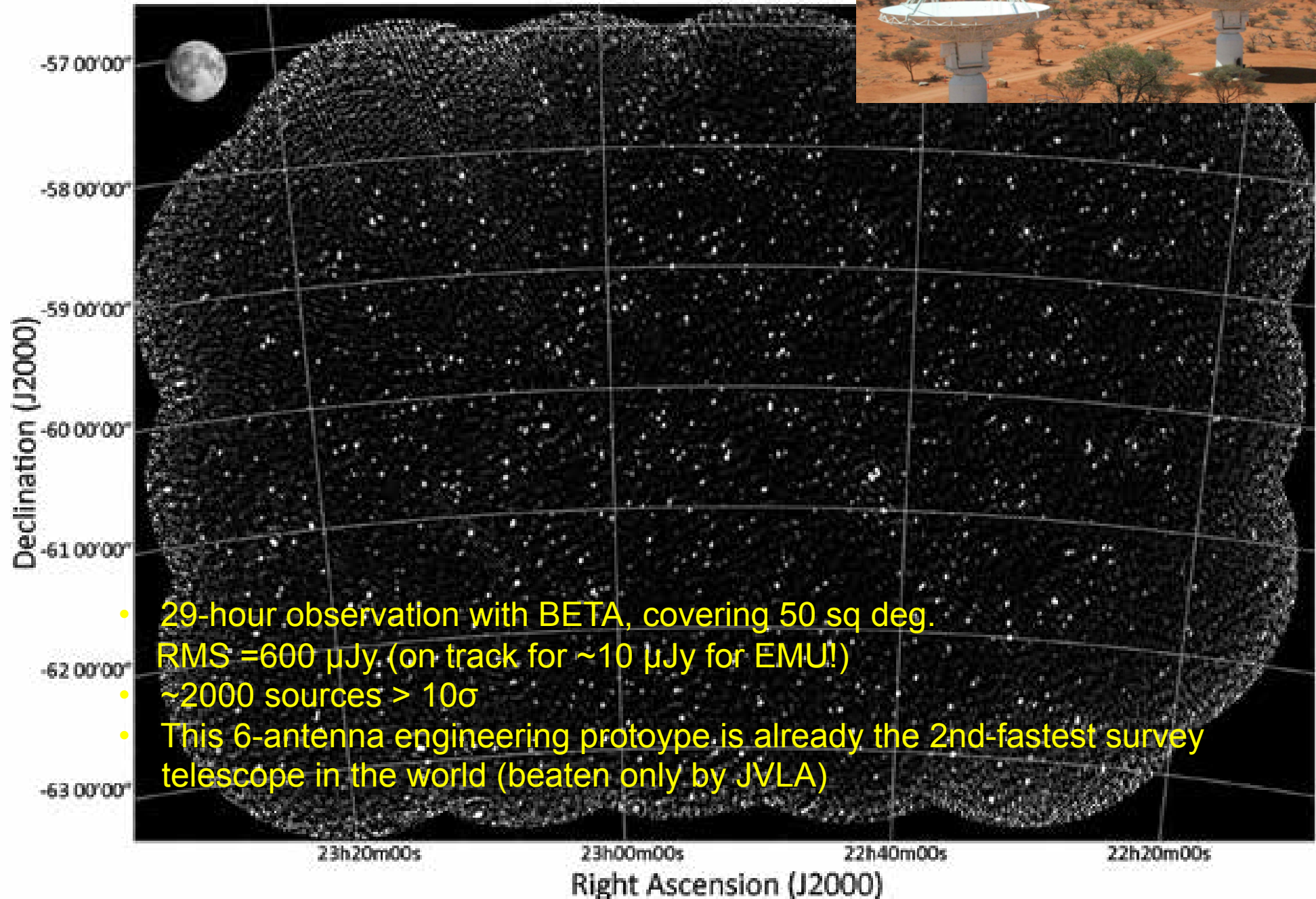
## Planned schedule

- 12 MkII PAFS installed by ~Dec 2015
- Early 2016: “shared risk” ASKAP early science
- All PAFs installed by mid-2016
- 2017: Full EMU survey starts ???????

# Current EMU status

- Currently doing BETA science
- Planning early science projects starting early 2016
- Planning “key science projects” for 2017
- Also inviting “User science projects”
- In all cases, research programs starting NOW!

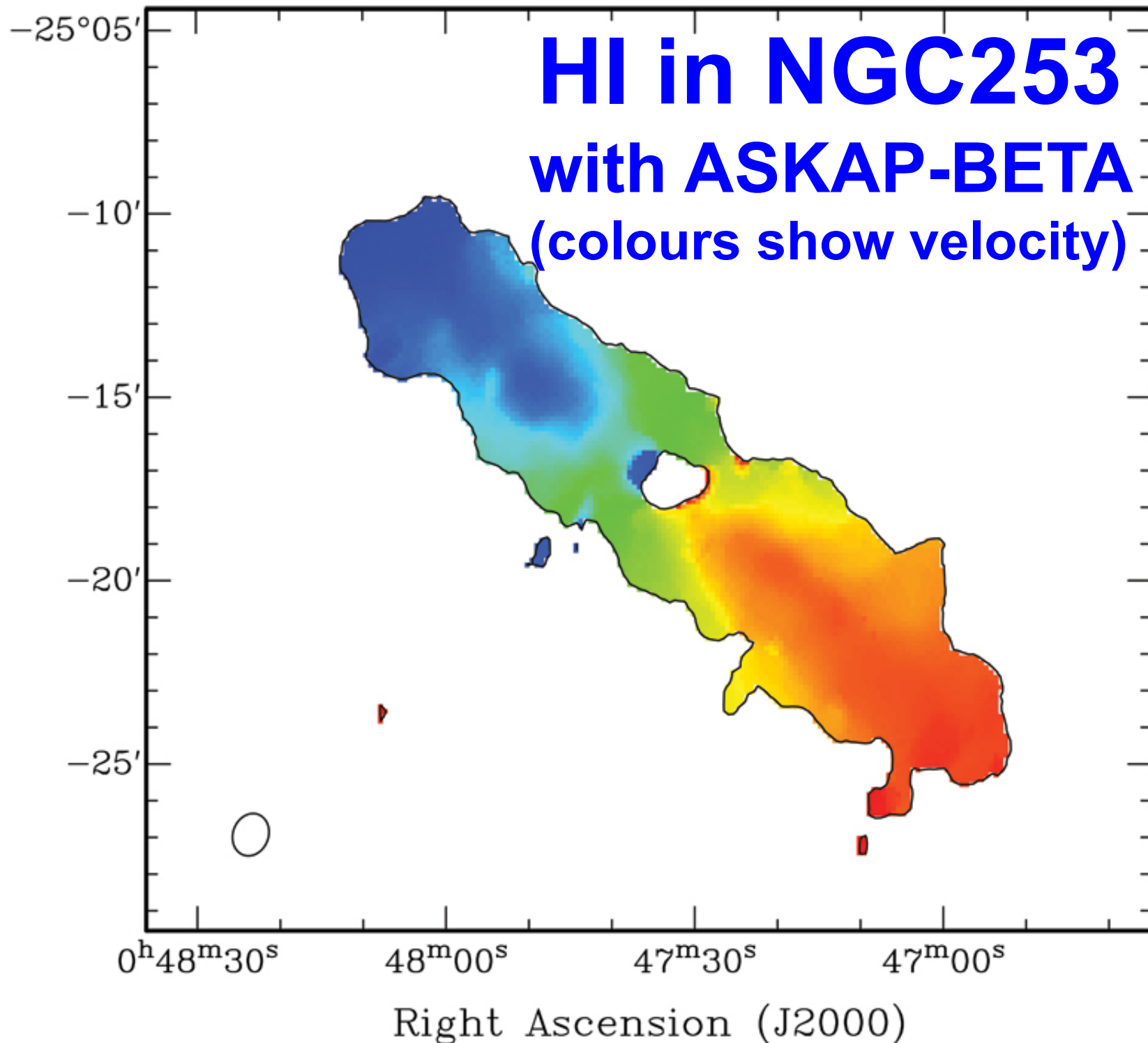
# PAFs work (even with only 6 antennas)!



- 29-hour observation with BETA, covering 50 sq deg.  
RMS = 600  $\mu$ Jy (on track for  $\sim 10$   $\mu$ Jy for EMU!)
- $\sim 2000$  sources  $> 10\sigma$
- This 6-antenna engineering prototype is already the 2nd-fastest survey telescope in the world (beaten only by JVLA)

# HI in NGC253 with ASKAP-BETA (colours show velocity)

Declination (J2000)



# EMU and its pathfinders



**ATCA – ATLAS**  
**(2006-2013)**  
**6 antennas single-pixel**



**ATCA – ATLAS - SPT**  
**(2013-2015)**  
**6 antennas single-pixel**



**ASKAP – early science**  
**(2016)**  
**12 antennas MkII PAF**



**ASKAP – EMU**  
**(2017-2018)**  
**30-36 antennas MkII PAF**

**Comparison: NVSS**  
 **$3\pi$  sr**  
**Rms=450  $\mu$ Jy**  
**1.8 million galaxies**

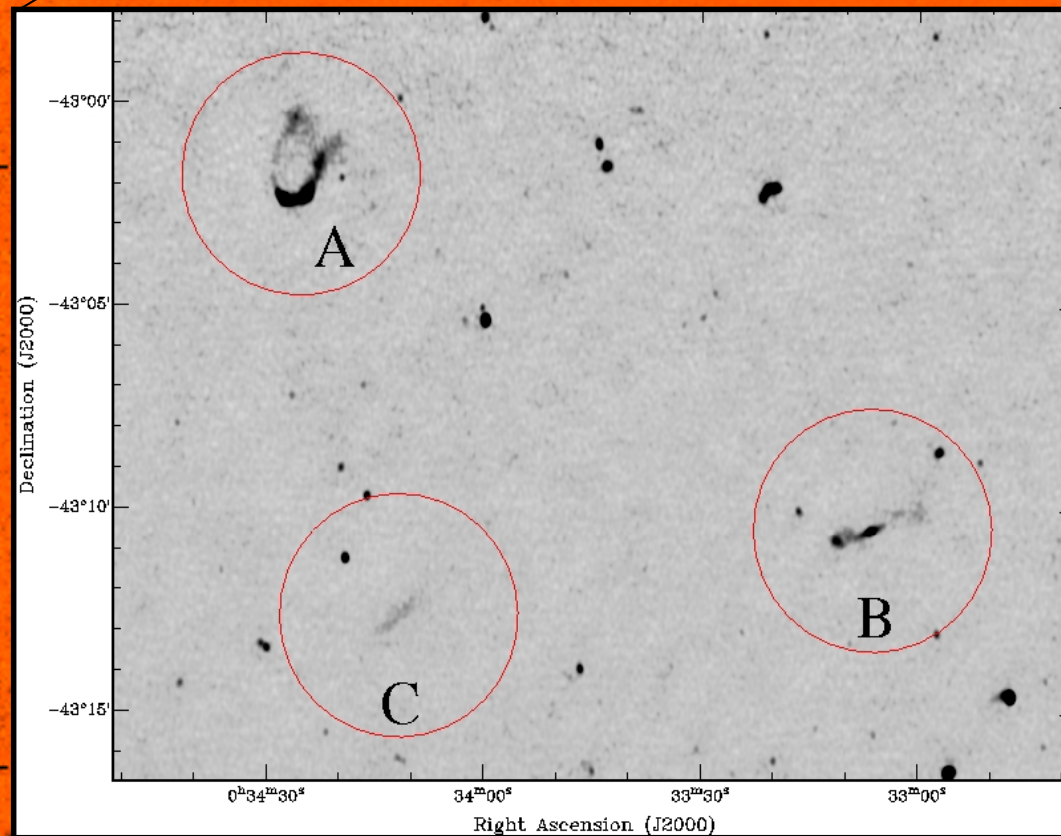
**7 sq deg**  
**Rms=15  $\mu$ Jy**  
**6000 galaxies**

**100 sq deg**  
**Rms=40  $\mu$ Jy**  
**30,000 galaxies**  
**300 clusters?**

**1000 sq deg**  
**Rms=30  $\mu$ Jy**  
**0.5 million galaxies**

**$3\pi$  sr**  
**Rms=10  $\mu$ Jy**  
**70 million galaxies**

# The EMU Pathfinder: ATLAS=Australia Telescope Large Area Survey 7 sq deg to rms=15 $\mu$ Jy



Mao et al. 2010MNRAS.406.2578M



Deep radio image of 75% of the sky (to declination  $+30^\circ$ )

Frequency range: 1100-1400 MHz

40 x deeper than NVSS

- 10  $\mu$ Jy rms across the sky

5 x better resolution than NVSS (10 arcsec)

Better sensitivity to extended structures than NVSS

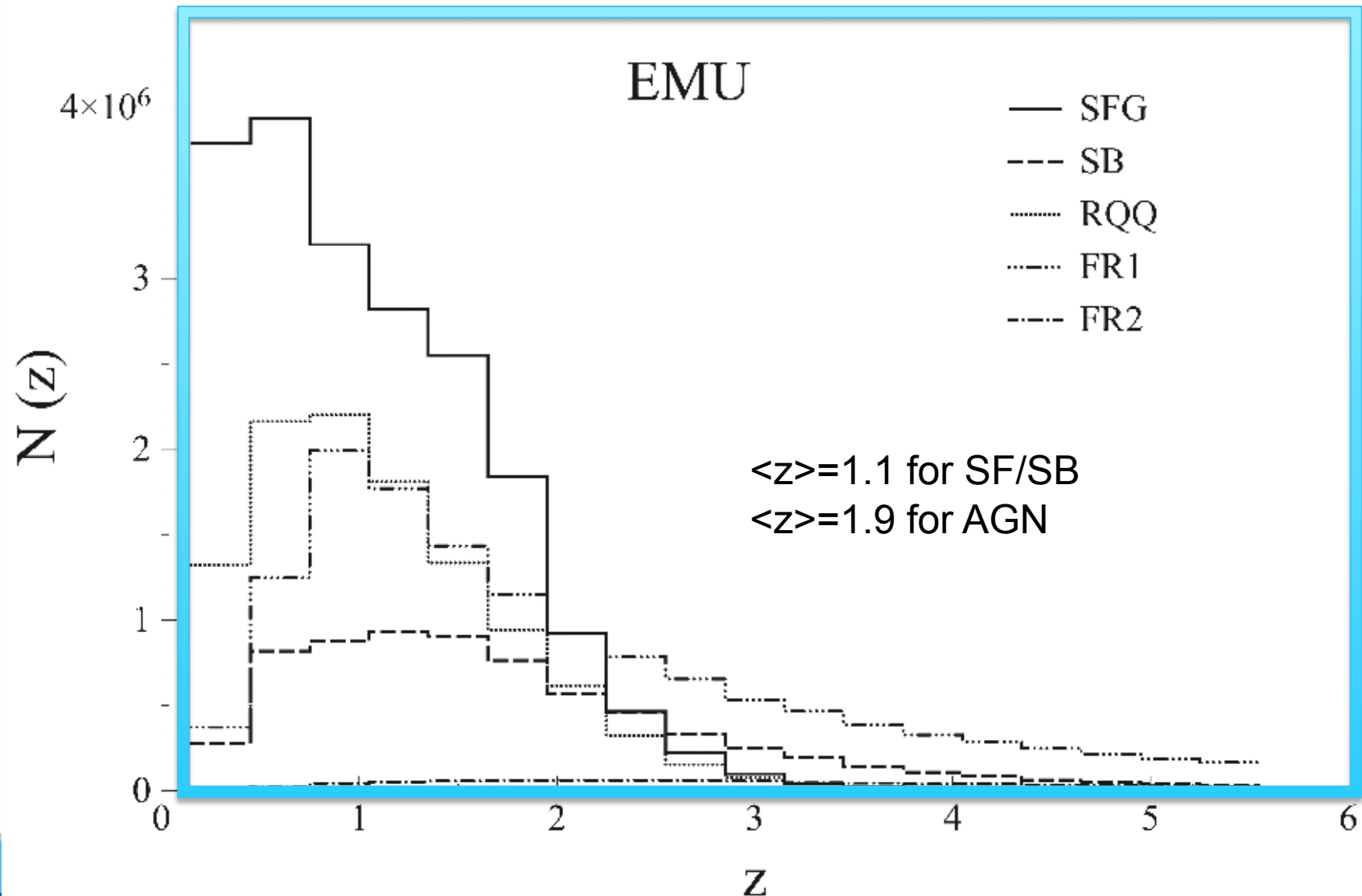
Will detect and image ~70 million galaxies at 20cm

All data to be processed in pipeline

Images, catalogues, cross-IDs, to be placed in public domain

Survey starts 2016(?)

# Redshift distribution of EMU sources



Based on SKADS (Wilman et al; 2006, 2008)

# EMU Project Structure

- **Ray Norris** (Project Leader)
- **Andrew Hopkins & Nick Seymour** (Project Scientists)
- **Anna Kapinska** (Project Manager)
- **Josh Marvil** (ASKAP Early Science Team Leader)
- **Ian Heywood** (Guru in residence)
- Coordinator and editor of a twice-yearly EMU newsletter (vacant)
- Editor (write and maintain) of the EMU public web page (vacant)

## The EMU's EGG

- The consultative group of ~30 active, involved, EMU members

## The EMU team

- ~220 team members from 17 countries

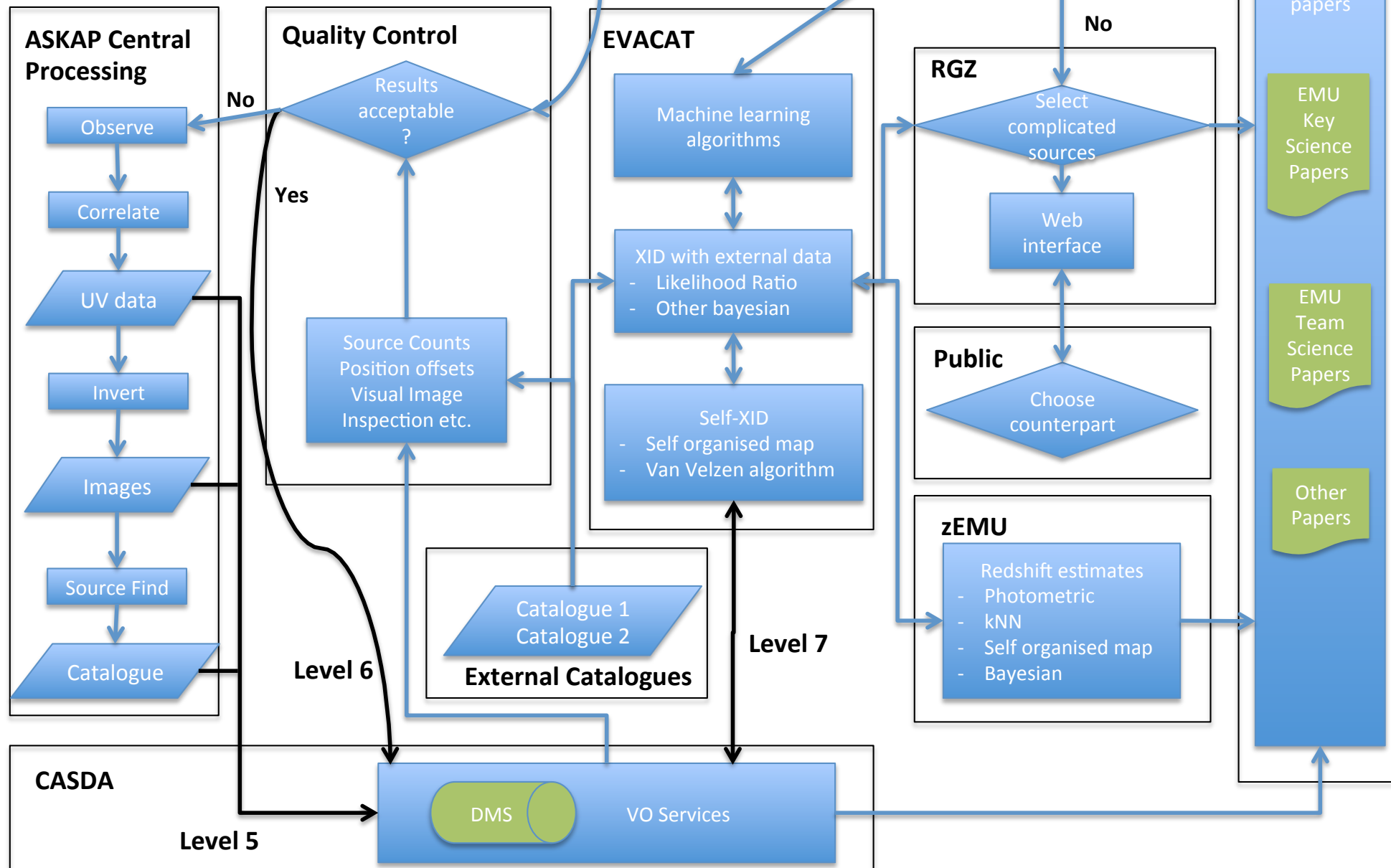
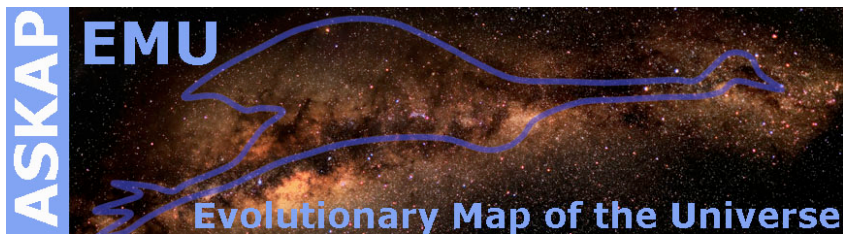
# Science Goals

- 1) **Evolution of SF from  $z=2$  to the present day,**
  - using a wavelength unbiased by dust or molecular emission
- 2) **Evolution of massive black holes**
  - how come they arrived so early? How do binary MBHs grow?
  - what is their relationship to star-formation?
- 3) **Explore the large-scale structure and cosmological parameters of the Universe.**
  - E.g, Independent tests of dark energy models
- 4) **Explore an uncharted observational parameter space**
  - almost certainly finding new classes of object.
- 5) **Explore Clusters and ultra low-surface-brightness radio objects**
- 6) **Generalise our understanding of the Galactic Plane**
- 7) **Create a legacy for surveys at all wavelengths (Herschel, JWST, ALMA, etc)**

**How did galaxies form and evolve?**

# How does EMU differ from earlier surveys?

- Scale – increases the number of known radio sources by a factor of  $\sim 30$
- Ambition – includes:
  - Cross-identification with optical/IR catalogues
  - Ancillary data (redshifts etc)
  - Key science projects as an integral part of the project
- Explicitly includes “discovering the unexpected”



# EMU Re-acceleration

- **ASKAP construction schedule delayed because of technical issues**
- **Now forging ahead again**

# Goals of EMU “re-acceleration”

Give the EMU project a makeover to

- ensure critical tasks are being actively worked on,
- ensure that the people who work on them will be rewarded for their efforts,
- provide incentives to work on EMU tasks,
- ensure we are able to write the key papers as quickly as possible after EMU data becomes available:
  - avoid half-baked papers
  - “hit the ground running”
  - Try out techniques/software on pathfinder data sets (ATLAS, COSMOS, ATLAS-SPT)

**Important: ensure that we write papers NOW  
(11 EMU journal papers so far).**

# How to get involved

- Join a key science project
- Join or propose an early science project
- Join or propose a “user science project”

--- or---

- Help out by building links to another survey  
(“EMU collaboration project”)
- Help out by developing techniques  
(“EMU development project”)

***Actively participating in any of these activities will result in your leading or co-authoring an EMU paper***

EMU Key Science Projects	Project Leader
EMU Value-Added Catalogue	Nick Seymour
Characterising the Radio Sky	Ian Heywood
EMU Cosmology	David Parkinson
Cosmic Web	Shea Brown
Clusters of Galaxies	Melanie Johnston-Hollitt
Cosmic star formation	<p><b>Each of these will generate a number of papers, starting now, and culminating in a key science paper. Each project has a team working on it. You can volunteer to join a team.</b></p>
Radio-loud AGN	
Radio AGN in the EoR	
Radio-quiet AGN	
Local Universe	
The Galactic Plane	
SCORPIO: Radio Stars	
WTF: Mining Data for the Unexpected	Ray Norris

See <http://askap.pbworks.com/KeyProjects> for details



# Examples of Proposed ASKAP Early Science Projects

Ian Heywood	Characterising the Radio Sky
Glen Rees	Radio cosmology
Andrew Hopkins	Radio-luminosity functions
Minh Huynh	RLFs of radio-loud AGNs
Anna Kapinska	RLFs of FR II radio galaxies
Ray Norris	Cluster sources
Jose M. Diego	Radio-IR correlation
Nick Seymour	Studies of Broadband AGNs
Chiara Ferrari	Dynamically active galaxy clusters
Tiziana Venturi	Radio emission in the Shapley Concentration:

**You can join these, or propose a new one.**

**Observations will start**

**~early 2016 using the early 12-antenna**

**ASKAP. Each project will produce at least one paper.**

# Examples of Proposed EMU User Science Projects

Rossella Cassano      Insight on the origin of giant radio halo from a mass-selected sample of galaxy clusters.

Nick Seymour      SFR as function of environment

Ray Norris      EMU Deep Field

Andrew Hopkins      Evolving IMF

**You can join these, or propose a new one. Observations will start ~ 2017. Each project will produce at least one paper.**

# Examples of EMU Collaboration Projects

eRosita  
SkyMapper  
WISE  
VHS  
LSST  
MWA  
Taipan  
DES/OZ-DES  
POSSUM  
XXL  
Radio Galaxy Zoo  
FP7-HELP

Nicolas Clerc et al  
Julie Banfi  
Tom Jarrett  
(TBD)  
Amy Kimball  
(TBD)  
Ray Norris  
Nick Seymour  
(TBD)  
Vernesa Smith  
Julie Banfi  
(TBD)

**You can volunteer to lead one of these, or propose a new one. Each project will probably produce at least one paper, and working on one will also earn you the right to be on other EMU papers.**

# Examples of EMU Development Projects

*(work on these buys authorship on papers)*

- Database storage and access
- Data quality & validation procedures
- ASKAPSOFT imaging
- Galactic Plane imaging
- Compact Source Extraction
- Diffuse Source Extraction
- Self-ID and cross-ID algorithms
- Spectroscopy
- Photometric redshifts.
- Statistical redshifts
- (Newsletter editor)

**You can volunteer to lead or join one of these, or propose a new one. Each project will probably produce at least one paper, and working on one will also earn you the right to be on other EMU papers.**

# Discussion

See [http://askap.pbworks.com/EMU\\_reacceleration](http://askap.pbworks.com/EMU_reacceleration) for more details

- Comments?
- Reactions?
- Suggestions?
- Questions?
- Suggestions for tasks?
- Suggestions for science papers?
- How can we generate papers now?
  - NB: 11 EMU journal papers so far!
- Any volunteers for (a) newsletter editor (b) web editor

**YOU ARE NOW LEAVING THE  
MURCHISON RADIO-ASTRONOMY  
OBSERVATORY  
THANK YOU FOR BEING RADIO QUIET**

