The SKA Molonglo Prototype (SKAMP) Project

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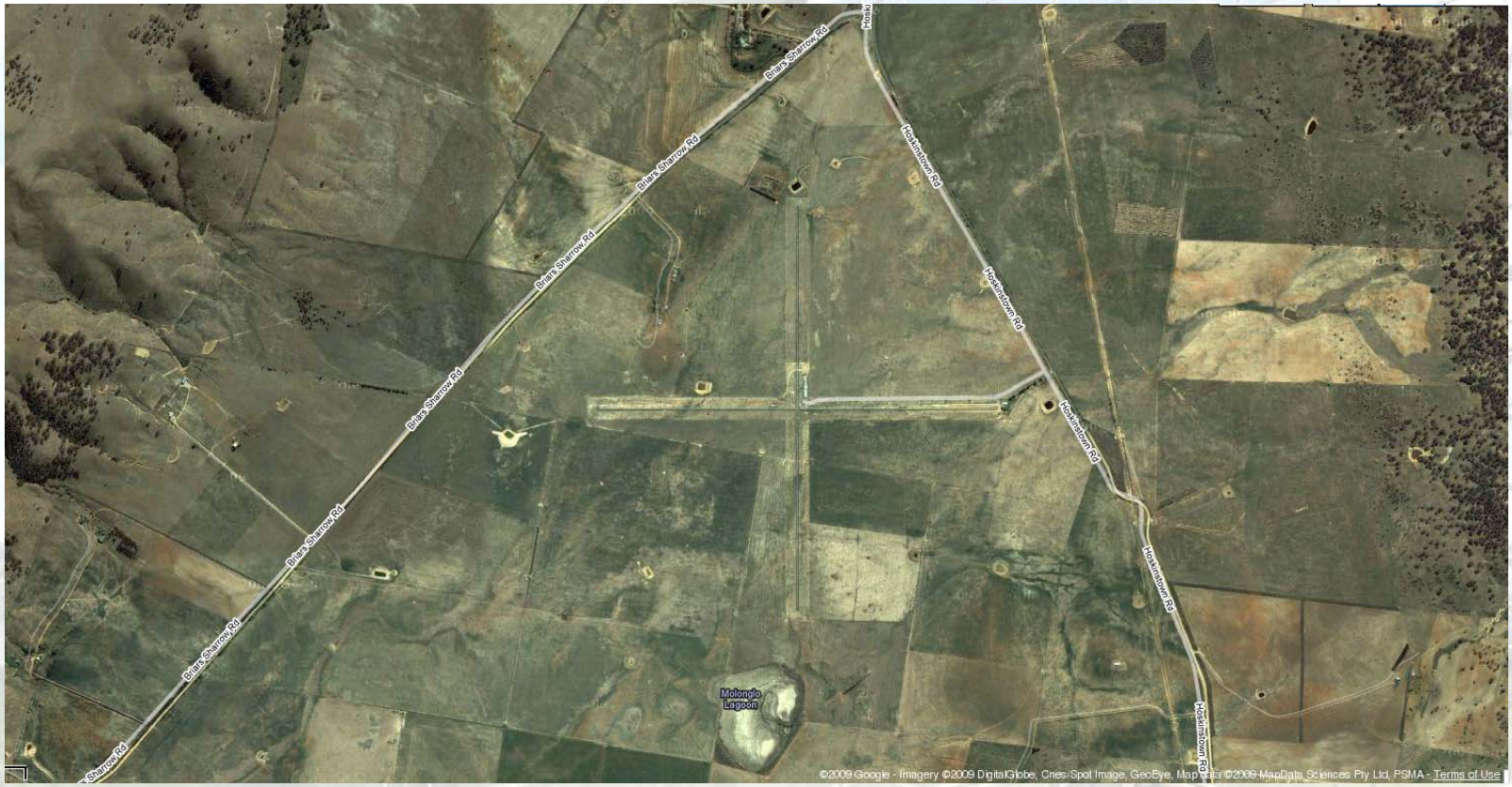


Google Map

Molonglo Observatory Timeline

- Past: Mills Cross
  - Official Opening: 19 November, 1965
  - 408 MHz, transit instrument
- Present: MOST (since 1981)
  - 843 MHz, synthesis imaging
  - Wide-field upgrade 1997
- Future: SKA Molonglo Prototype (SKAMP)
  - Spectral line & polarimetry capability

* MOST = Molonglo Observatory Synthesis Telescope

SKA Molonglo Prototype Project (SKAMP)

- Project Goals: new signal pathway with spectral line capability, dual polarisation line feed, room temperature electronics, wideband digital signal processing, wide field of view, RFI mitigation.
- Science & technology precursors for the SKA.
- Workshop Aims: identify key science projects and any technical developments needed for implementation.

Observing with the MOST

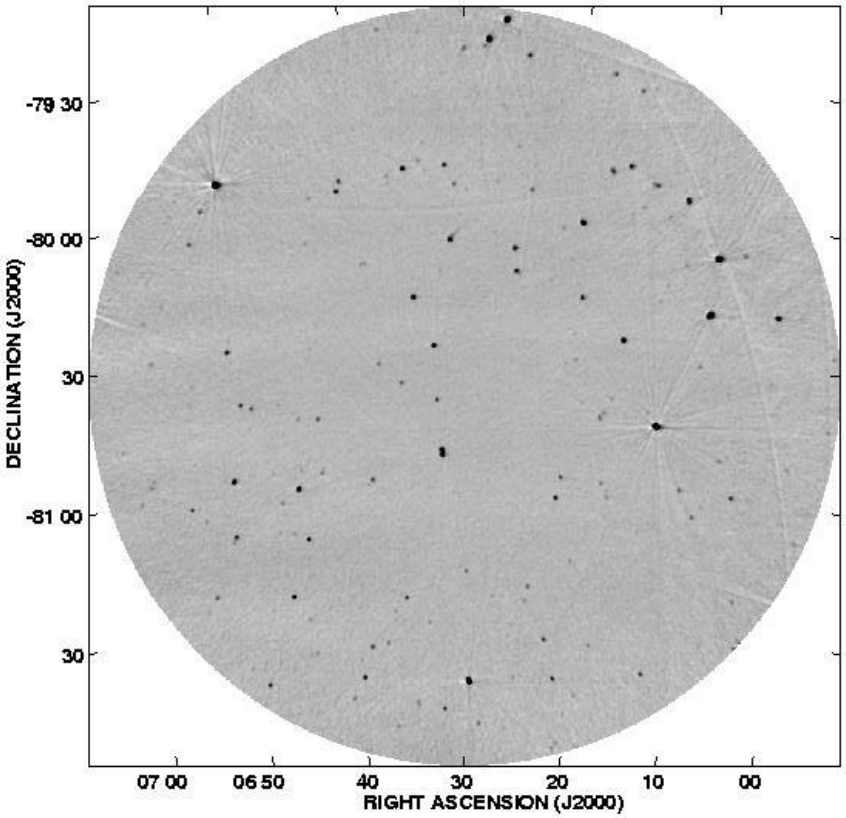
- Strengths - large collecting area(18,000 m^2), large extent (1.6 km), highly redundant array
- Single frequency - 843 MHz continuum
- 3 MHz bandwidth, RHC polarisation
- 43" spatial resolution (declination dependence)
- Field of view (since 1997): > 5 square degrees
- Sensitivity (1σ rms in 12 hrs): 0.8 mJy/beam
- Automatic 12 hr survey mode – poor snapshot capability – good TOO response
- Open access for data – ARC funded operations

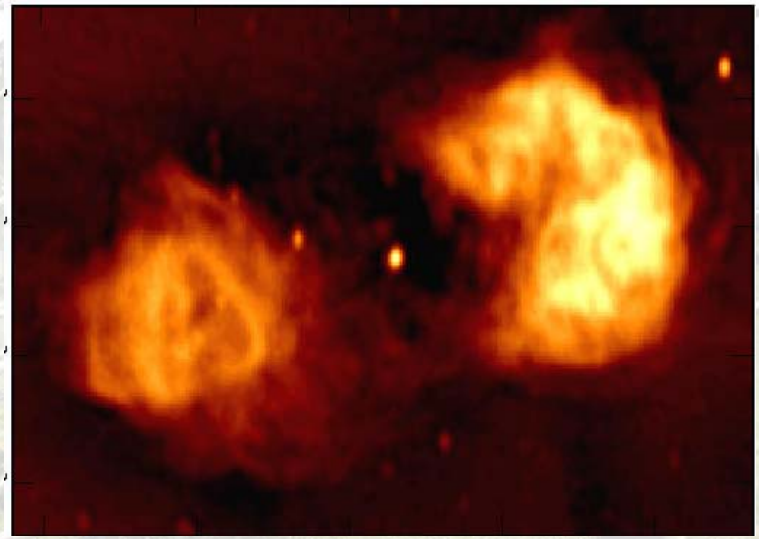
Imaging survey at 843 MHz

SUMSS & MGPS-2 source catalogues completed

Individual 12-hour fields are combined in 4^o x 4^o mosaics.

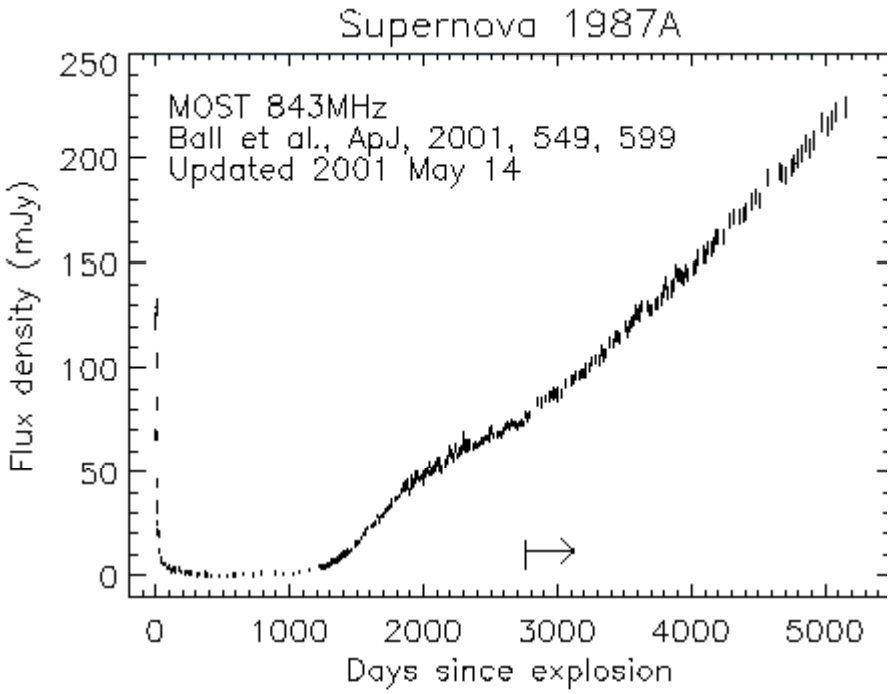
More than 250,000 sources stronger than 6 mJy/beam.

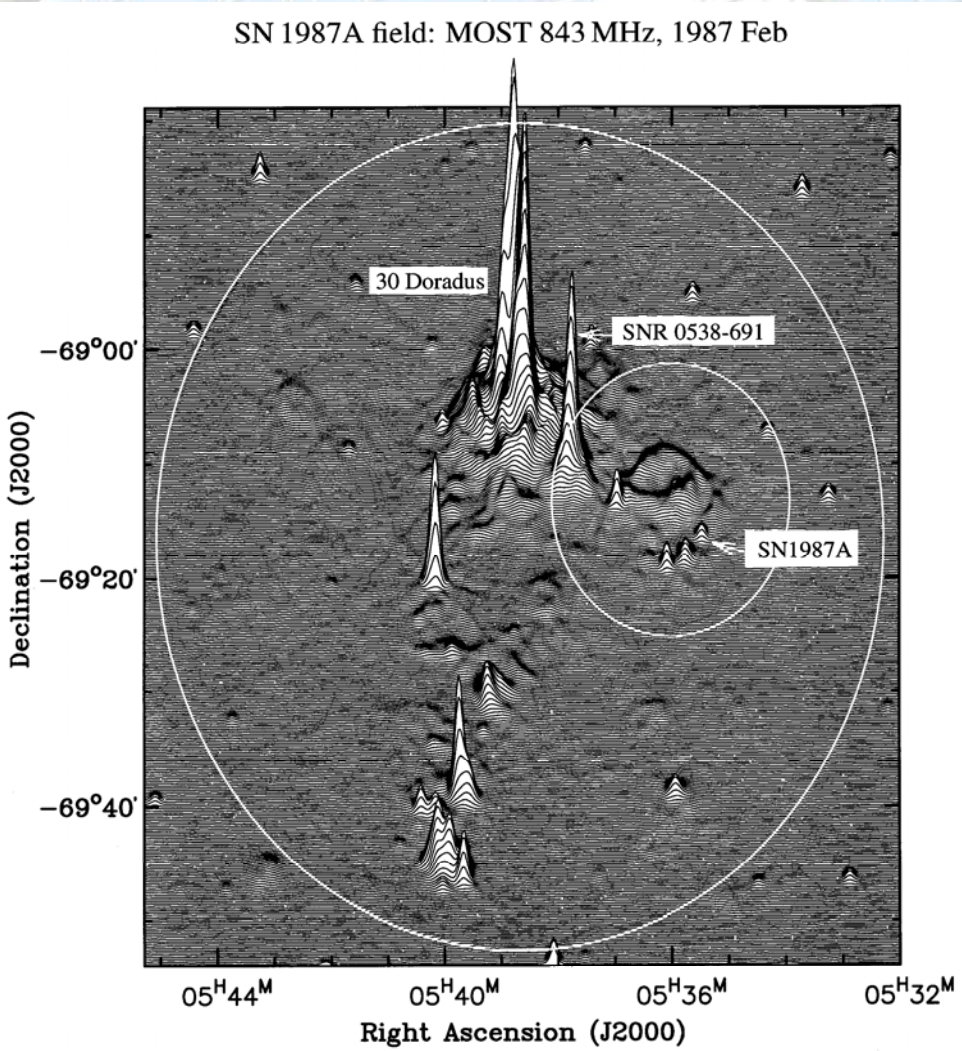




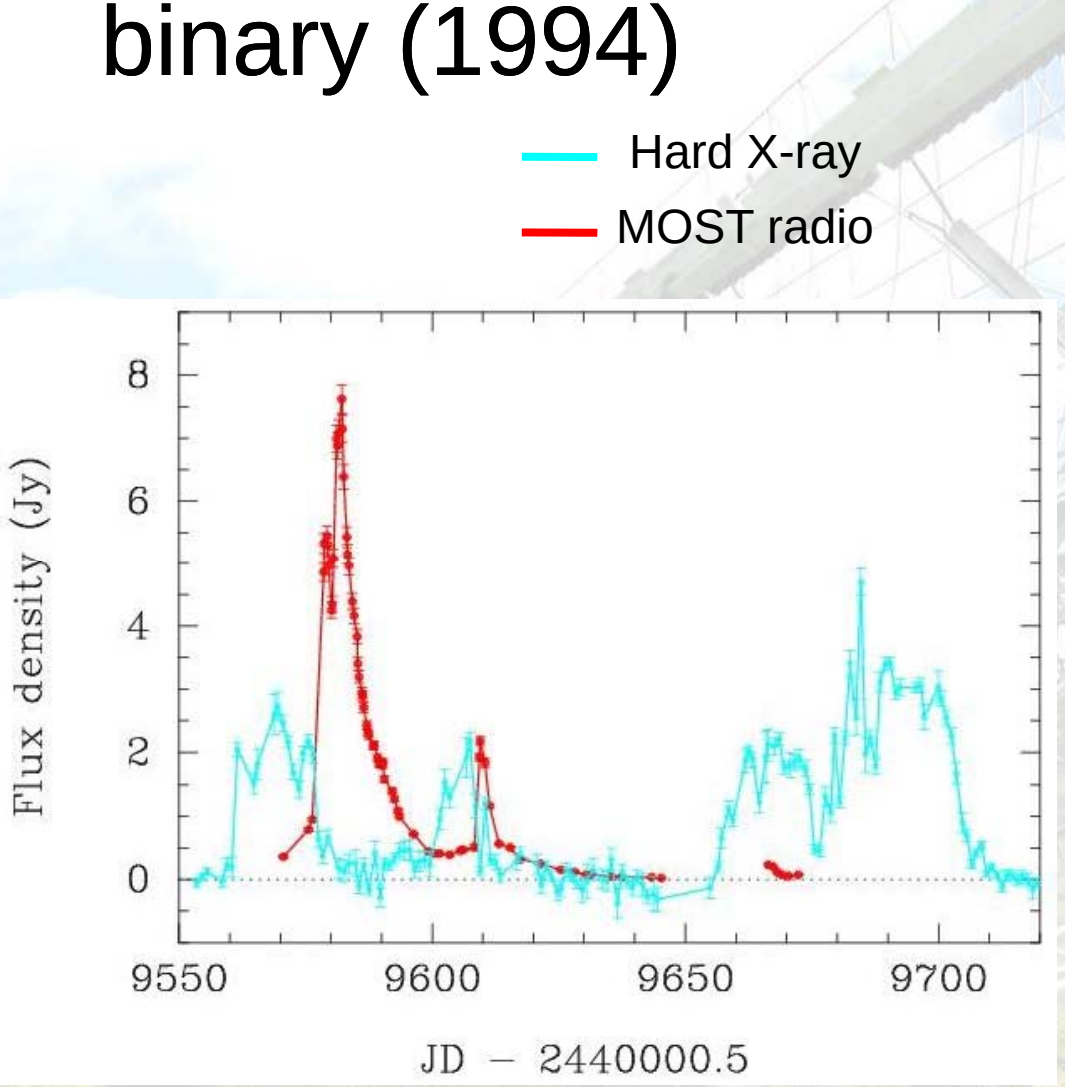
Radio Galaxy: Fornax A

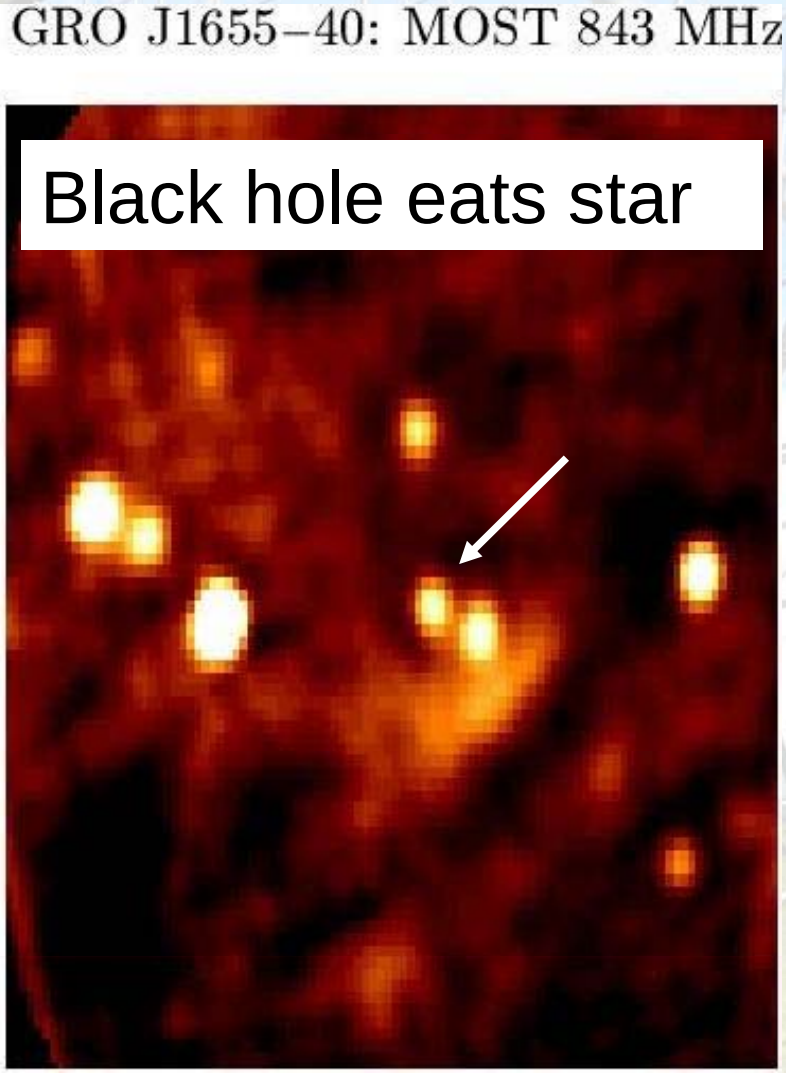
Supernova 1987A – the MOST light-curve (transient monitoring program)





GRO J1655-40: the brightest X-ray binary (1994)



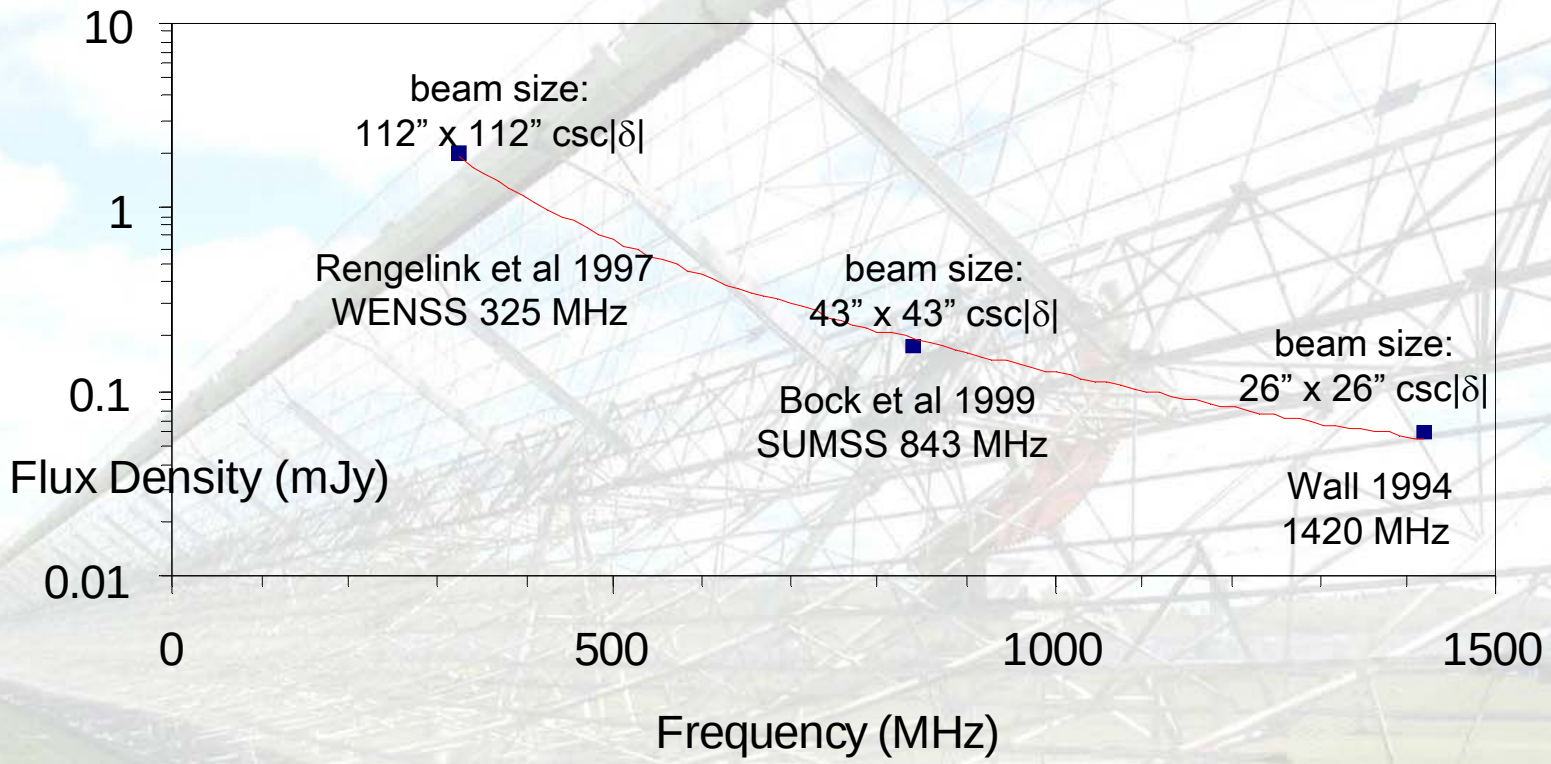


SKAMP: 3-stage project

- Stage 1: Proof of concept for 96 station correlator, develop data pipeline
- Stage 2: Spectroscopy with front-end unchanged, 30 MHz bandwidth, 2000 channels
- Stage 3: Dual polarised feed (700 - 1100 MHz prototype tested), select in 100 MHz bands, remesh to reduce leakage, 6000 channels @ 14.4 kHz, 30 second integration

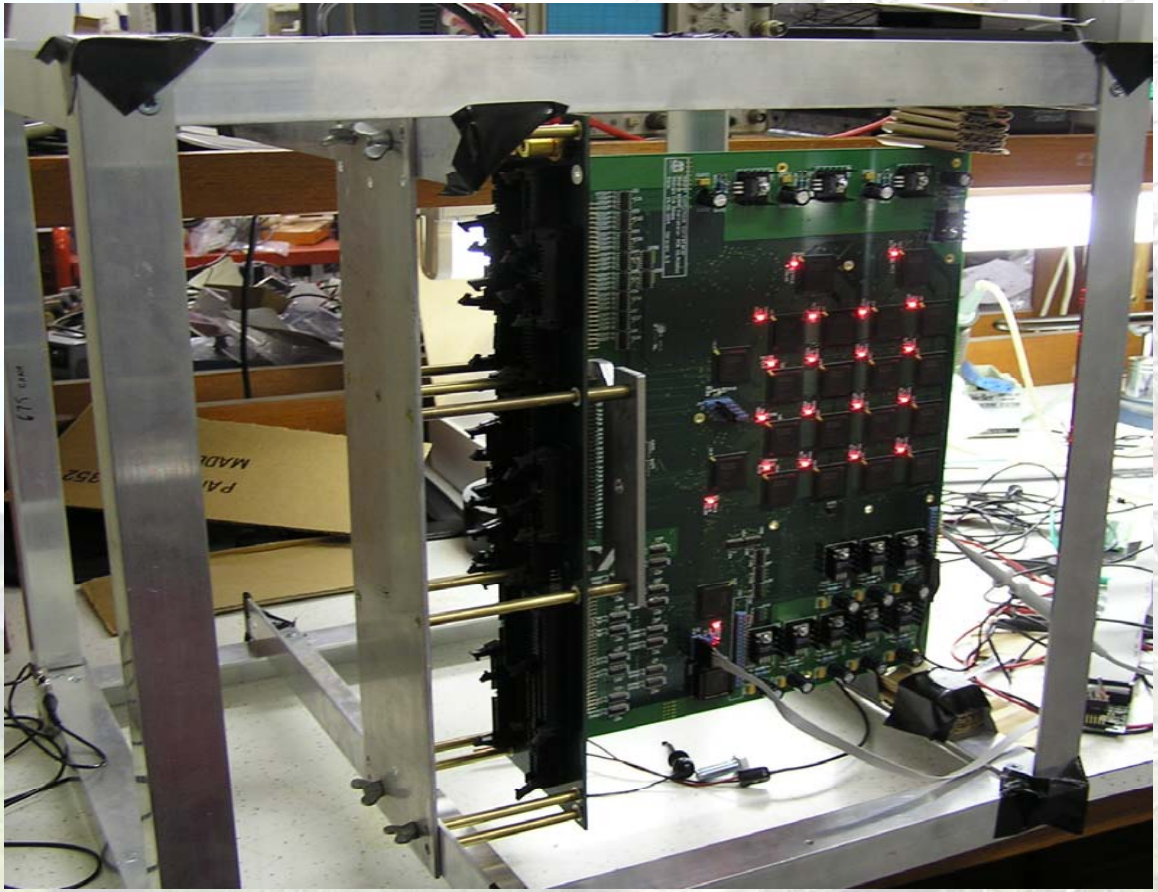
Staged development so science continues with minimum disruption

Confusion limits for Molonglo @ 843 MHz (10 beams/source) at δ = –60°



43“ spatial resolution: total intensity confusion limit is 0.12 mJy/beam
Spectroscopy & polarimetry discriminate via an additional parameter

Stage 1 - narrowband correlator

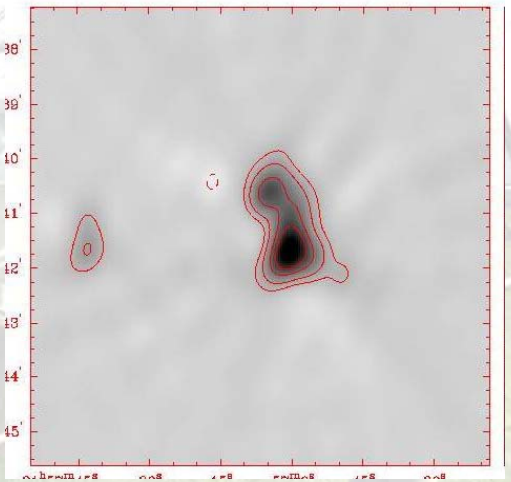


Adams & Bunton

- Proof of concept
- 96 stations
- 4000 baseline pairs

but only 131 independent

- 843 MHz
- Continuum data



Optic fibre network installed – digital signal transport from 88 independent stations

Stage 2 - spectral line capability

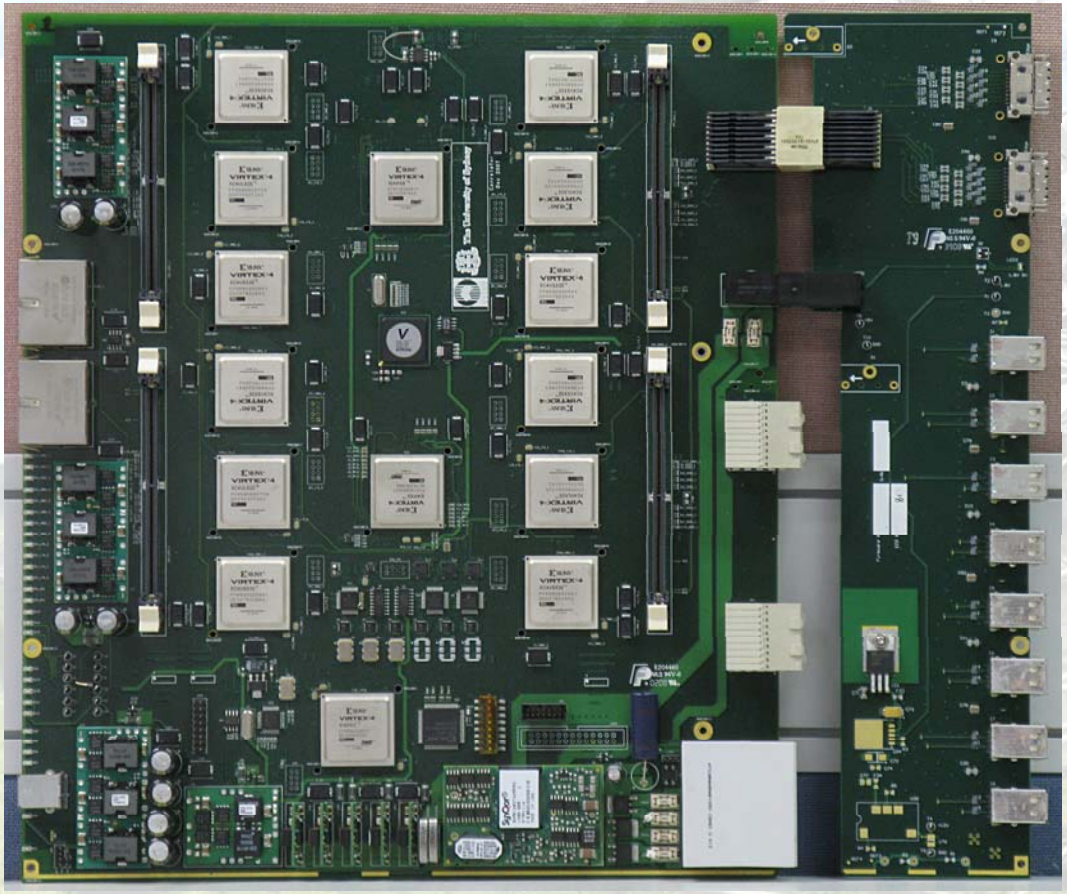
3D data cubes with (α, δ, frequency)

- 830 - 860 MHz
- 2000 channels
- Field of view: 4 deg^2
- Sensitivity (12 hr)

1σ ~ 0.15 mJy/beam

for full 30 MHz BW

Full spectral line correlator

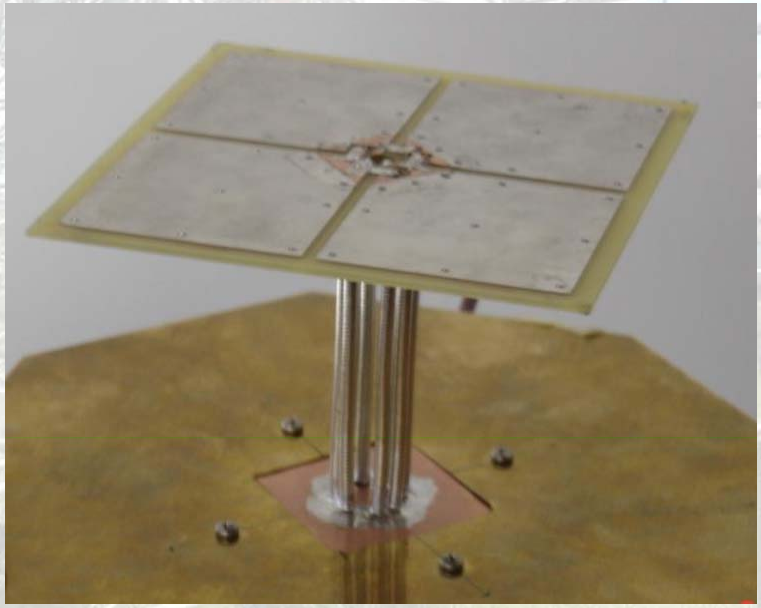


- Hardware & firmware
- 800 FPGAs
- 30,000 correlation cells
- 24 boards
- Plan for ~100 MHz BW
- Data rate 0.2 GB/sec
- Data file 30 GB (12 hr) with redundancy compression
- 30 sec integration time

Dual feed system for 6-m Reference Antenna for adaptive noise cancellation

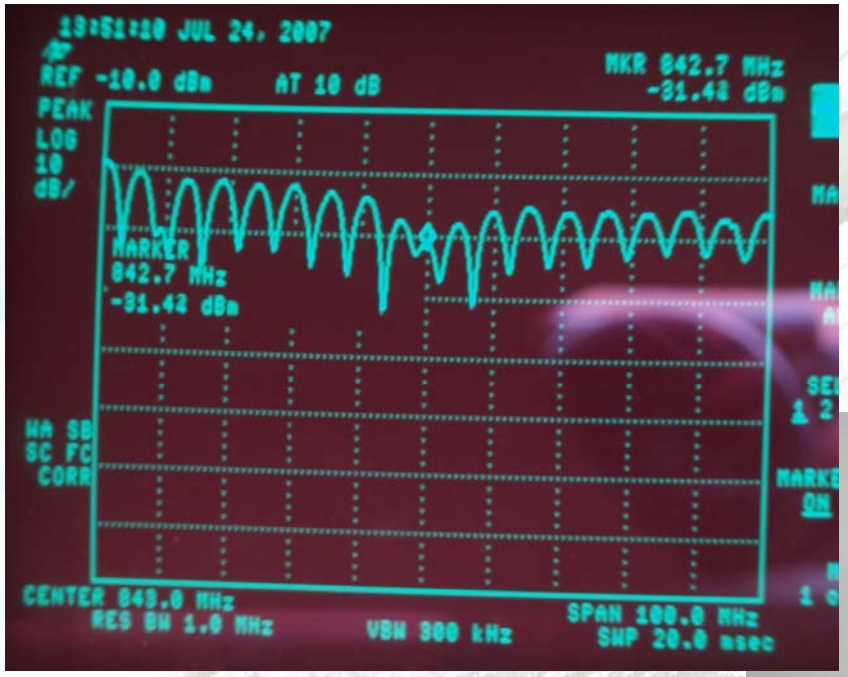
Stage 3 - wideband feed (prototype)

- 8-element module, 1.4 m length
- Wide-band dipoles – no moving parts
- Polarisation axes oriented along & across axis of feed
- Range tested for 700 -1100 MHz



(Leung)

First light through new line feed



- Double mesh – reduces leakage
- Predict 15 K improvement in T_{sys}
- First light through arrayed module

Rapid Prototype Telescope (RPT)

Observing with the SKAMP system

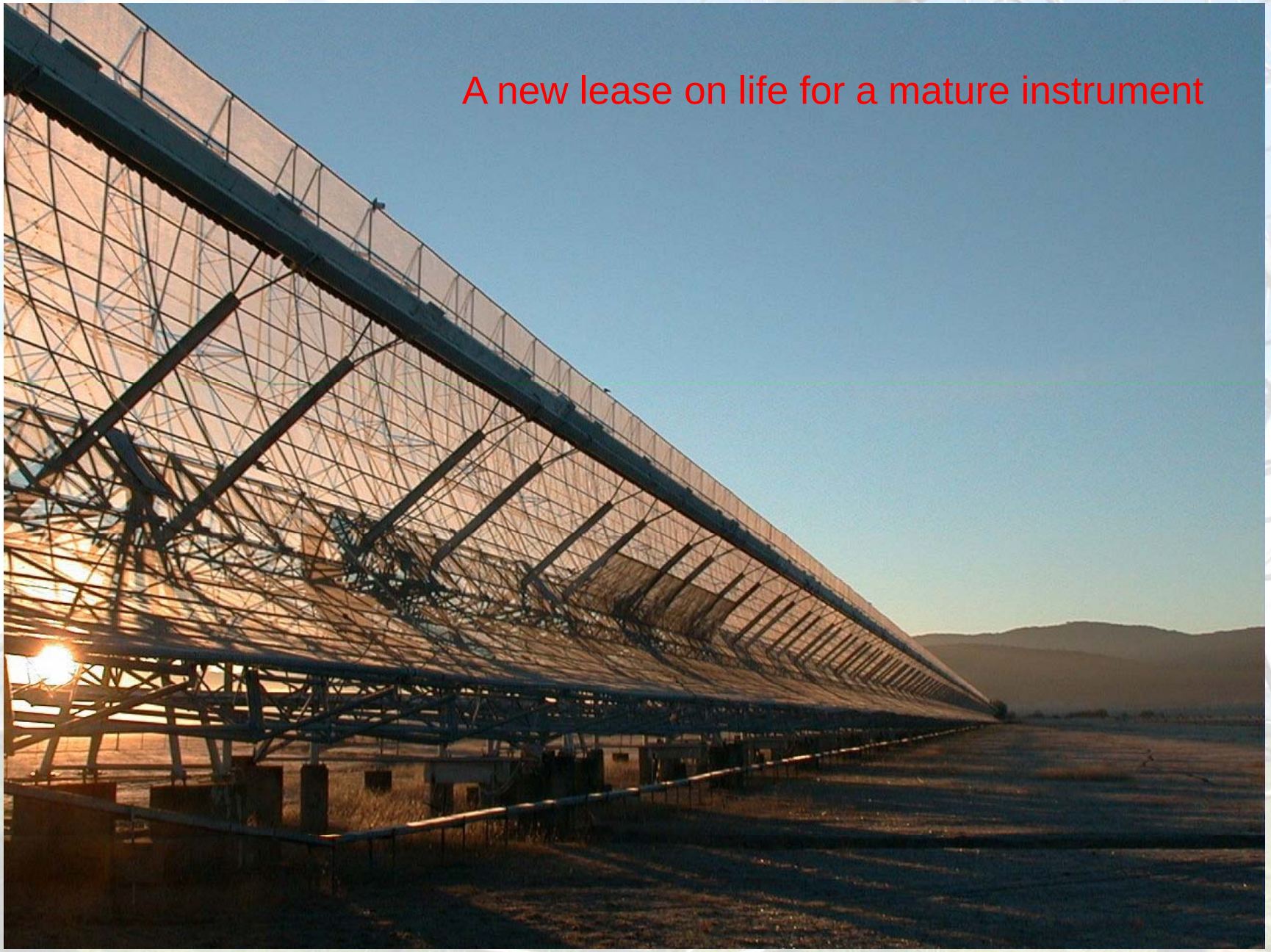
- Technical specifications on website
- Standard observing modes: survey, TOO options, snapshot only rarely
- Data pipeline to archive, open access after calibration & quality control
- Observing file & scheduling in-house?
- Option to request time through a TAC?
- Operational budget from ARC grants – external assistance necessary

SKAMP key science goals

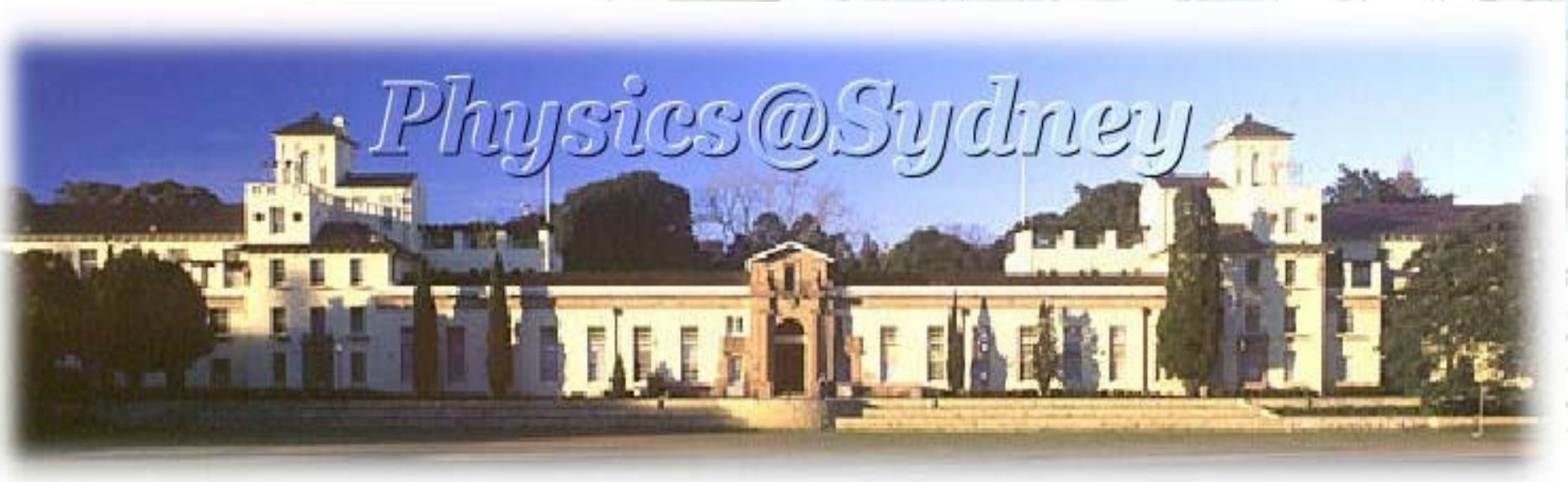
1. Blind survey of HI absorption in high redshift galaxies. Test models for mass-assembly of galaxies.
2. Search for OH megamasers in disks around super-massive black holes (z ~1).
3. Transient & variable sky - new phase space
4. Cosmic magnetism studies – diffuse Galactic polarisation and Rotation Measure.
5. Radio recombination lines (H199α is 841MHz)

Summary of SKAMP Project status

- Stage 1: Narrowband correlator operational – data pipeline under test
- Stage 2: Signal pathway fully designed & partly implemented; production soon of digital system
- Stage 3: Dual polarization 8-element feed module installed on testbed antenna. Beamformers in prototype.


A new lease on life for a mature instrument

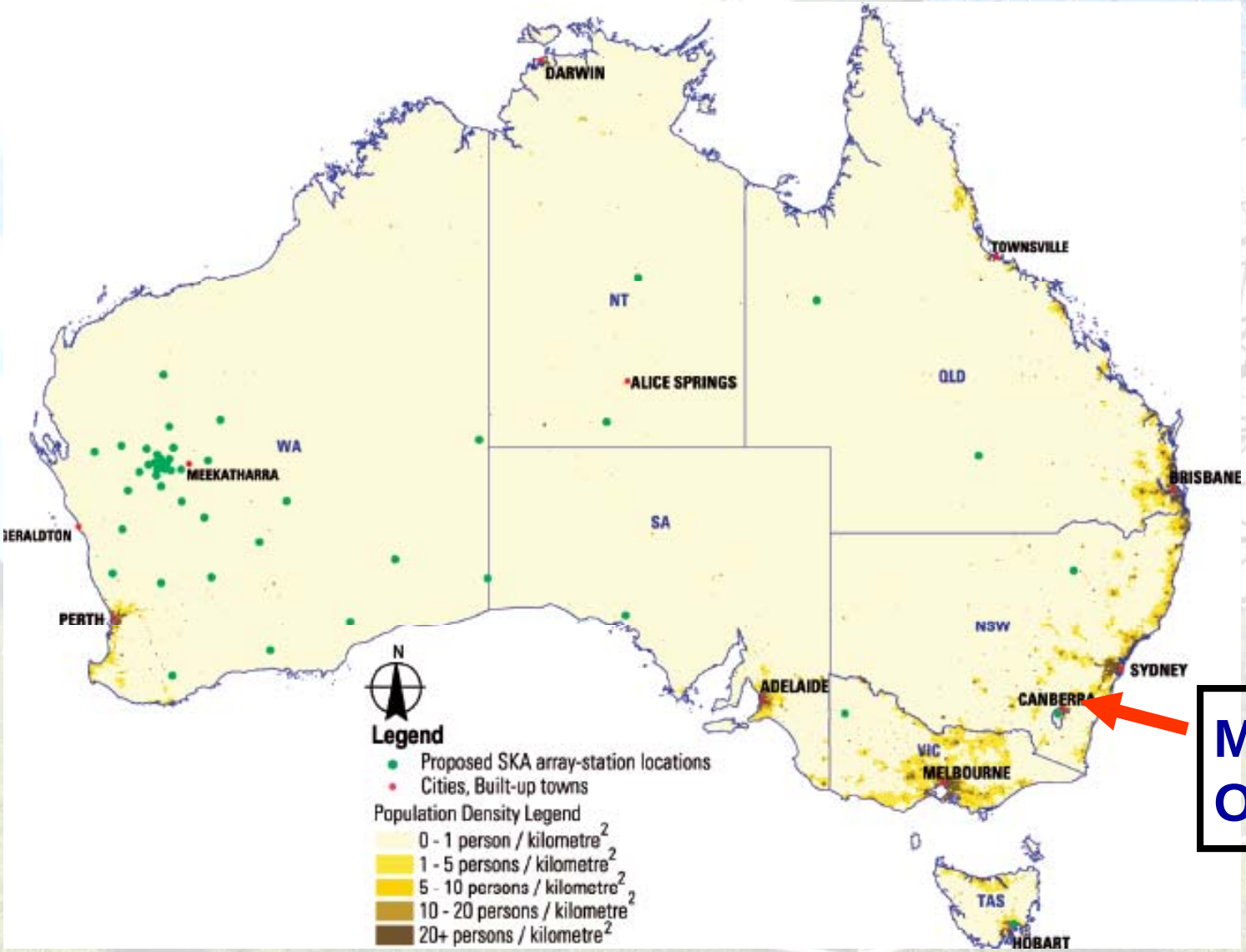
The School of Physics



Built 1924
Architect - Lesley Wilkinson

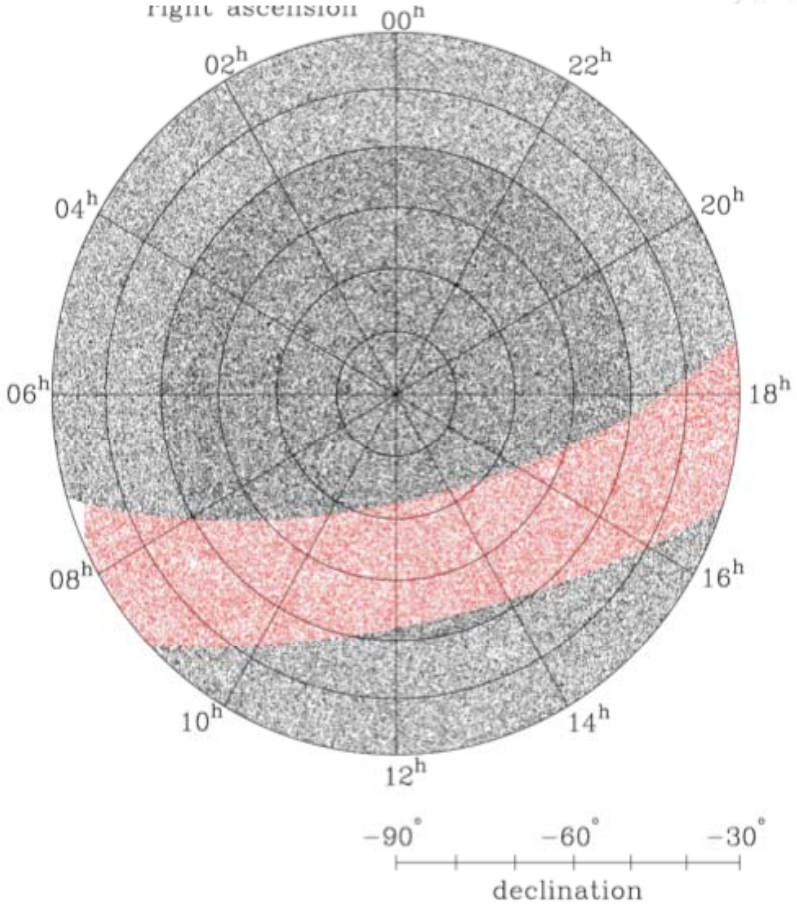
100 Academic staff
30 Admin & technical officers
130 Postgraduate students
40 Honours students
1400 Undergraduate students

Australia



Molonglo Observatory

SUMSS & MGPS-2 source catalogues



Flux limit:
6 mJy at δ <-50°
10 mJy at δ >-50°

Completeness limit:
8 mJy at δ <-50°
18 mJy at δ >-50°
Both for |b| >10^{o}

Black dots: extragalactic survey (SUMSS) - uniform sensitivity

Red dots: Galactic survey (MGPS-2) - dynamic range limited

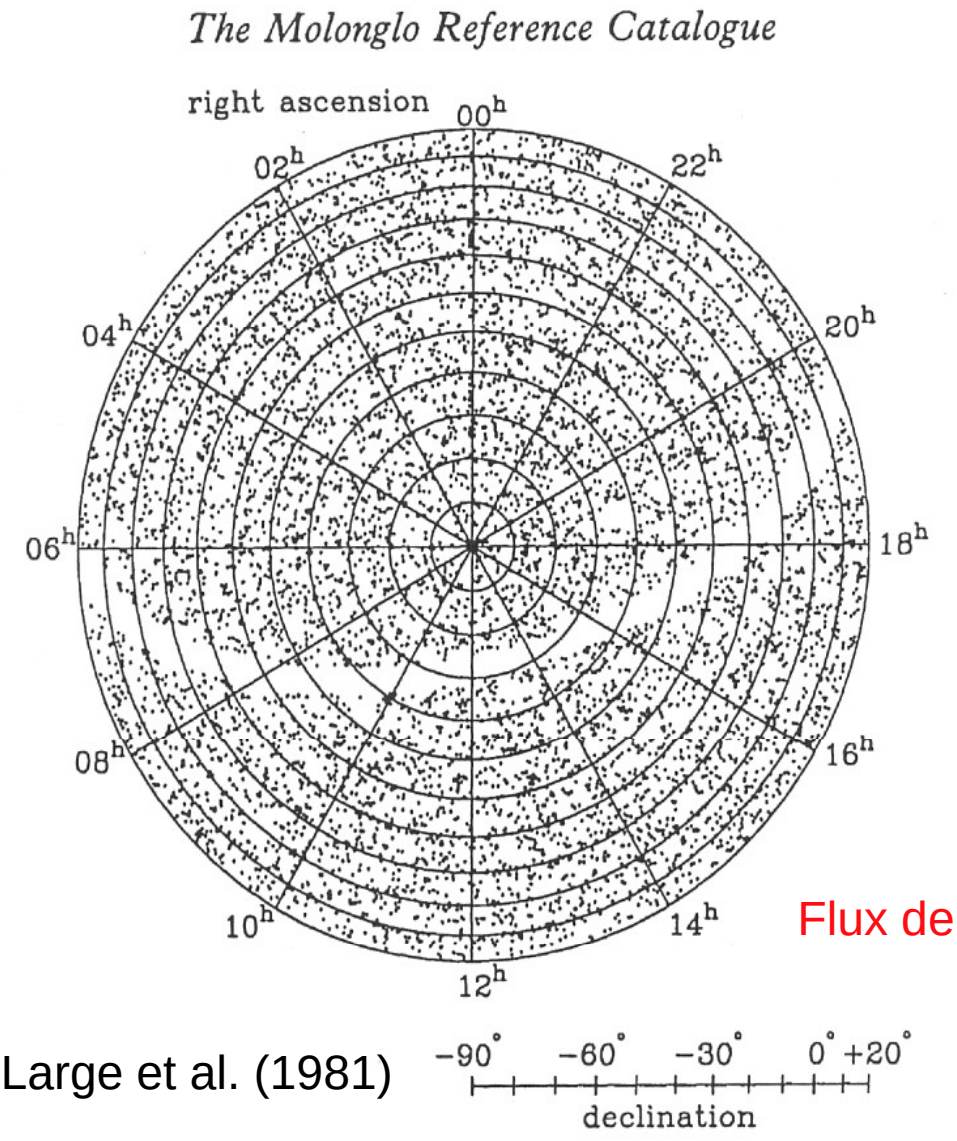
Principal Science Goals for MOST

- Imaging survey of the whole southern sky (SUMSS, MGPS-2)
- Source catalogue to study active galaxies (AGN) & star-forming galaxies in the local Universe
- Galaxies at high redshift
- Low surface brightness objects such as giant radio galaxies, cluster relics
- Transient source searches & monitoring
- Census of supernova remnants and HII regions

Molonglo 40th Anniversary Celebrations

Photos: Shaun Amy & Bill Tango

Molonglo Reference Catalogue



Large et al. (1981)

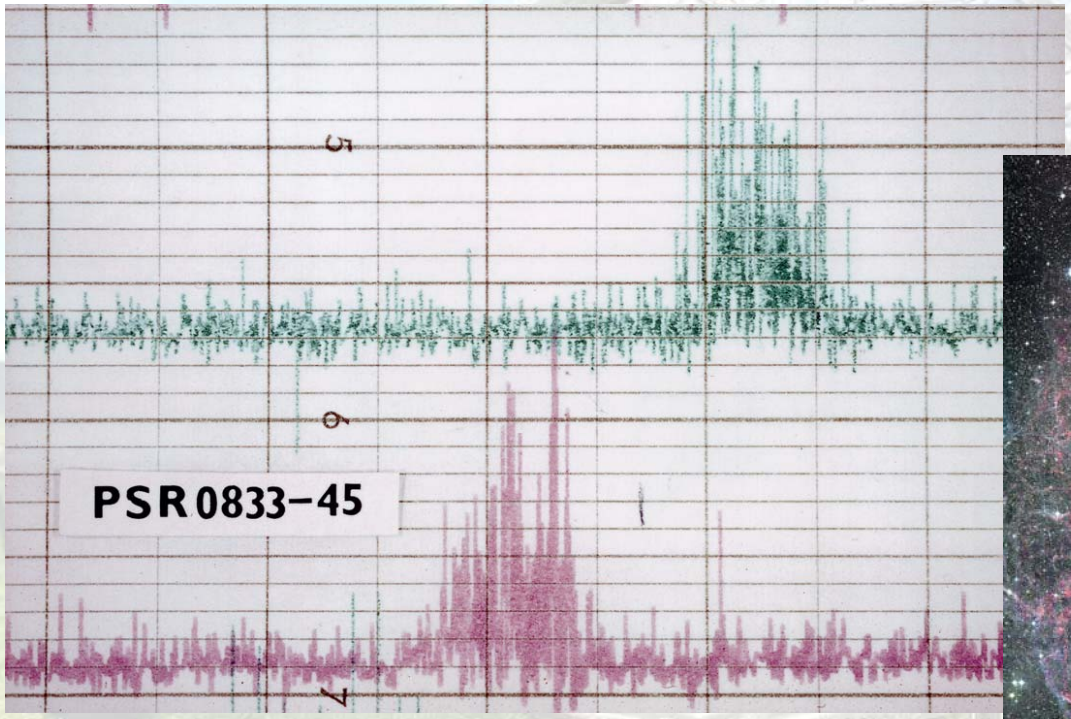
Specifications:

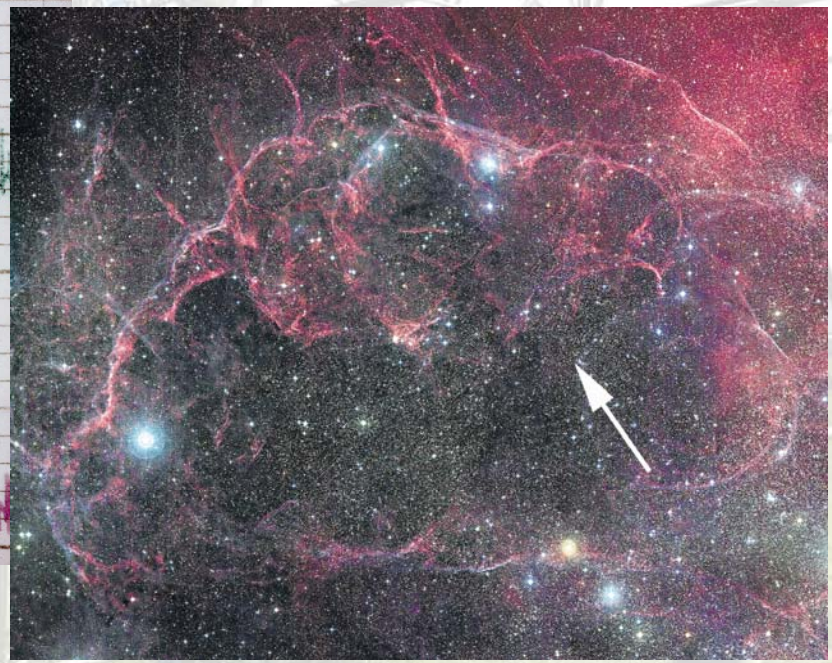
- >12,000 sources
- Flux limit > 0.95 Jy
- Sky covered $\delta \leq +18.5°$
- Resolution 3 arcmin

Flux density scale: I Jansky (Jy) = 10^{-26} W m^{-2} Hz^{-1}

Discovery of the Vela pulsar & the pulsar-SNR connection

(Large, Vaughan & Mills 1968)

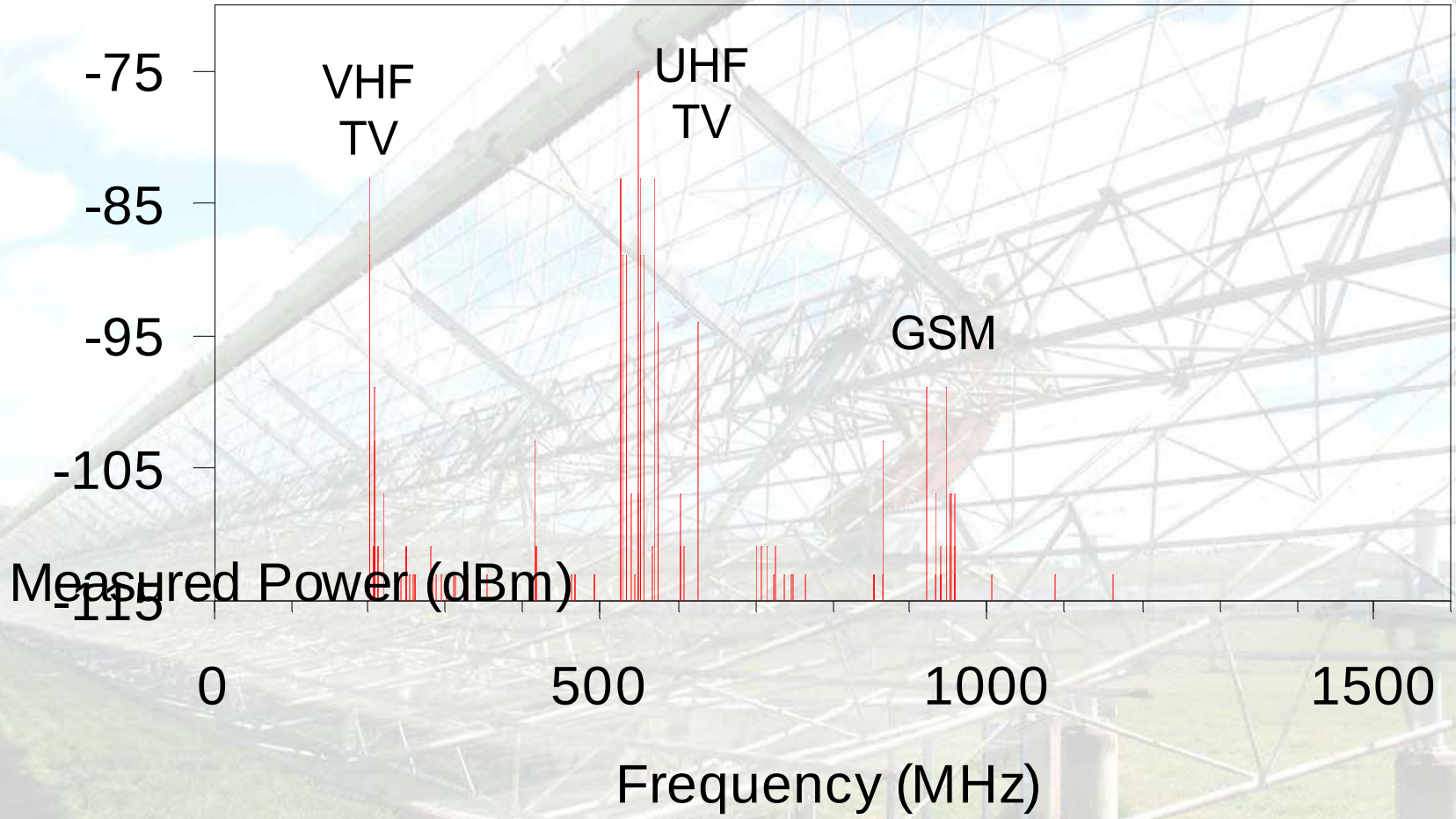




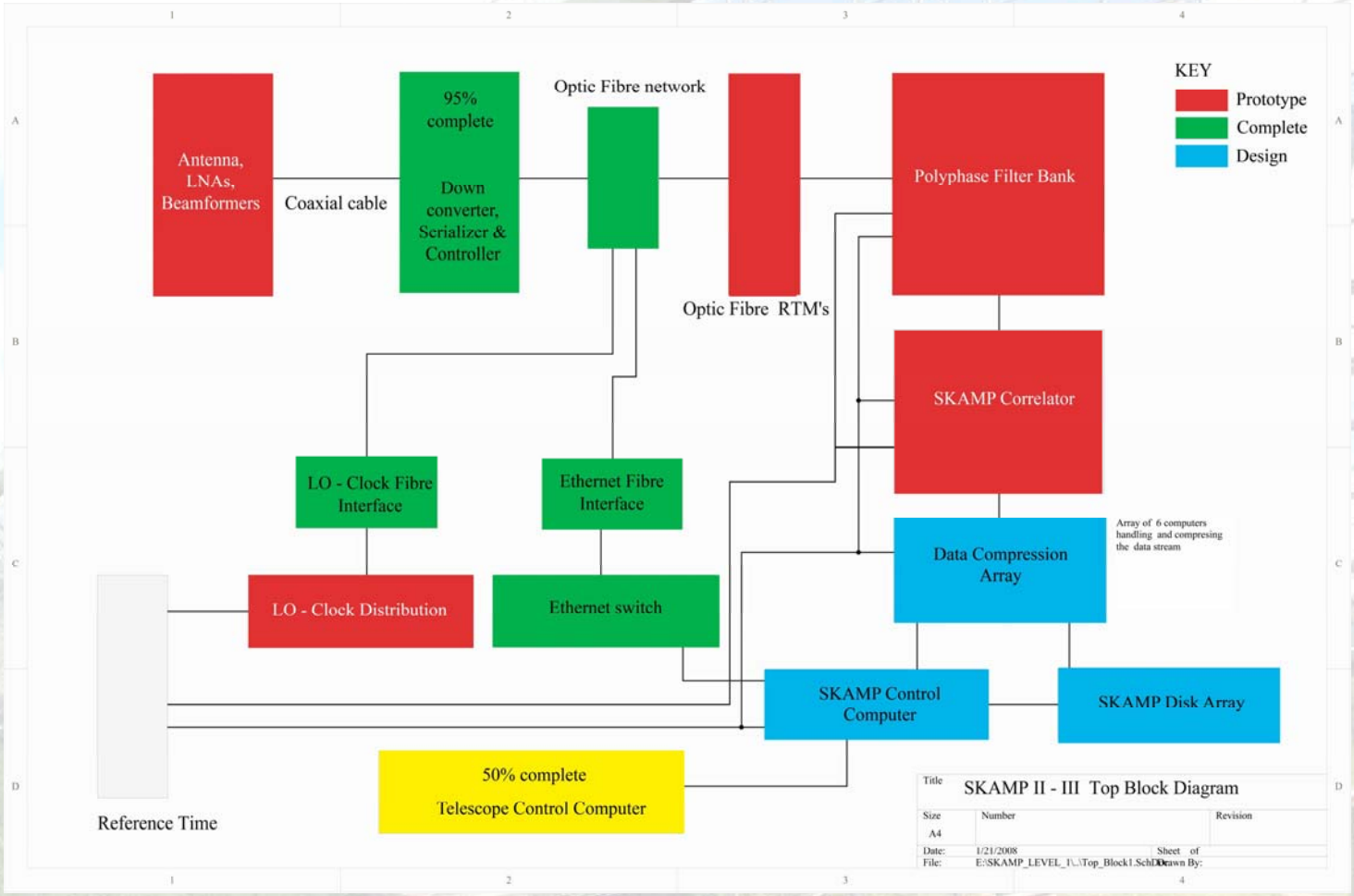
SNR = supernova remnant

RFI at Molonglo 200-1500 MHz

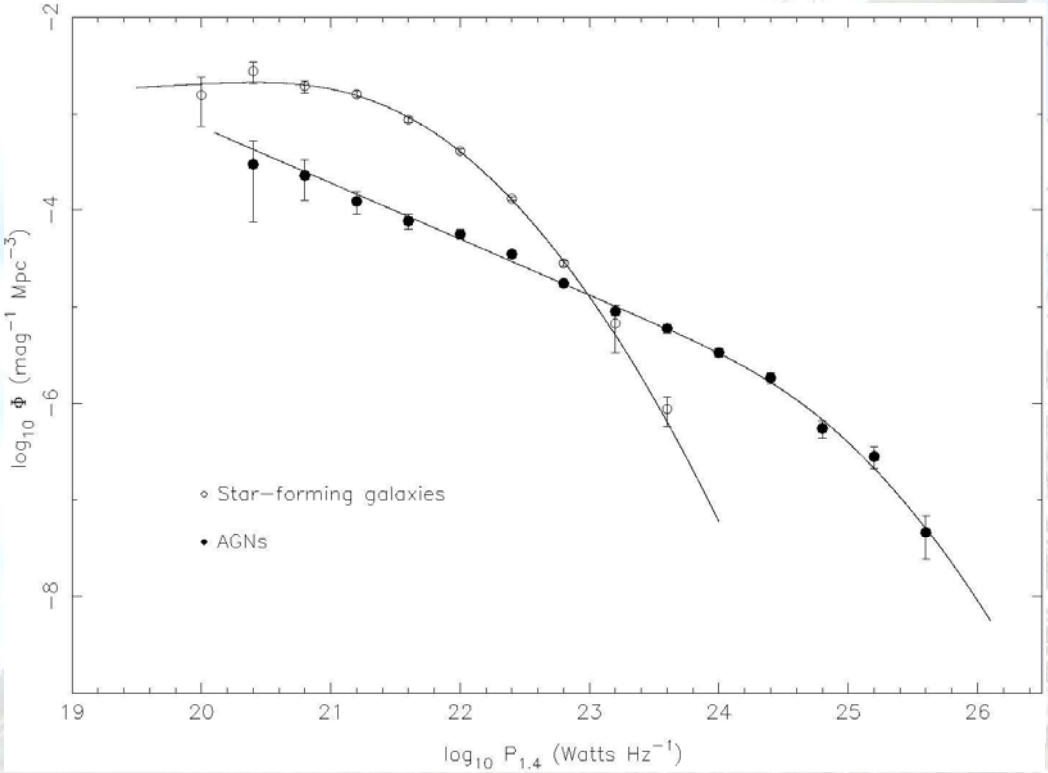
(Measured June 2001 – Mitchell & Briggs)



Block diagram of SKAMP signal pathway



What galaxies are in the local Universe?

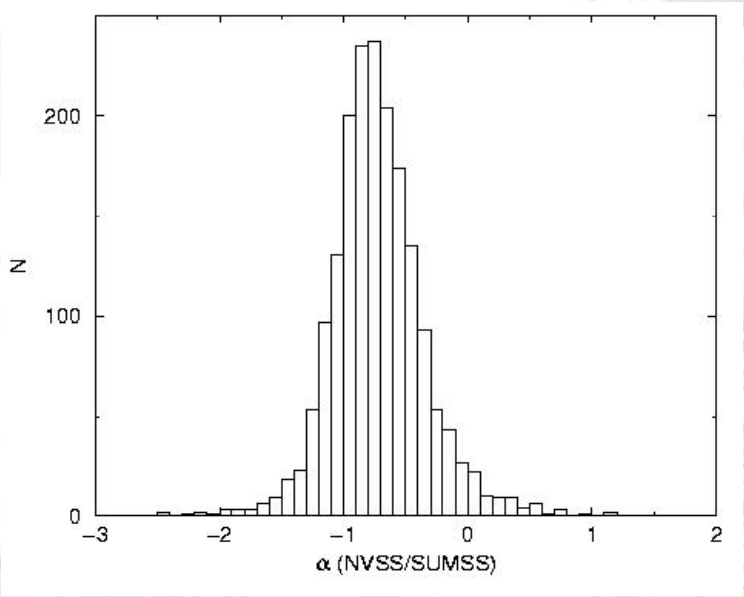


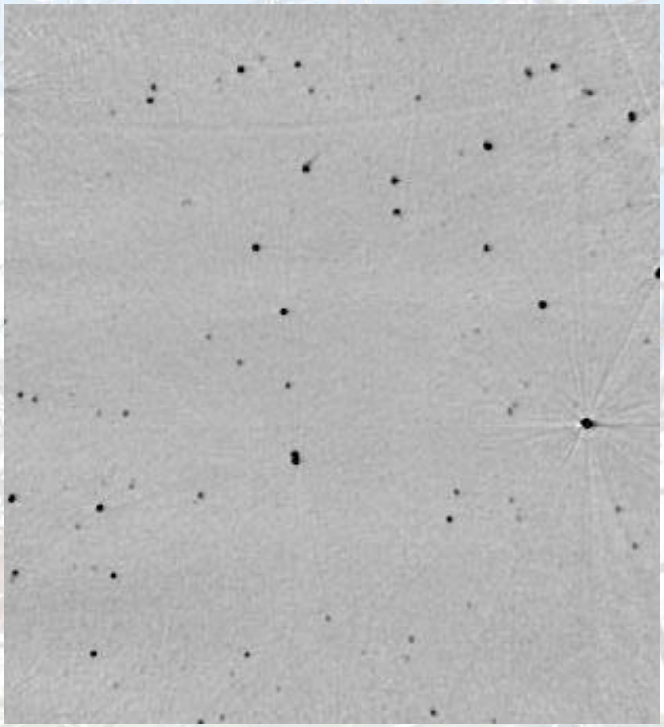
- ~40% are active galaxies (AGN)
- Powered by accreting supermassive black holes.
- Dominate the radio source population above $P_{1.4}= 10^{23}$ W Hz^{-1}

- ~60% are 'normal' star-forming galaxies
- Dominate radio source population below $P_{1.4}=10^{23}$ W/Hz

(Mauch 2005)

Expected source density and spectral index distribution



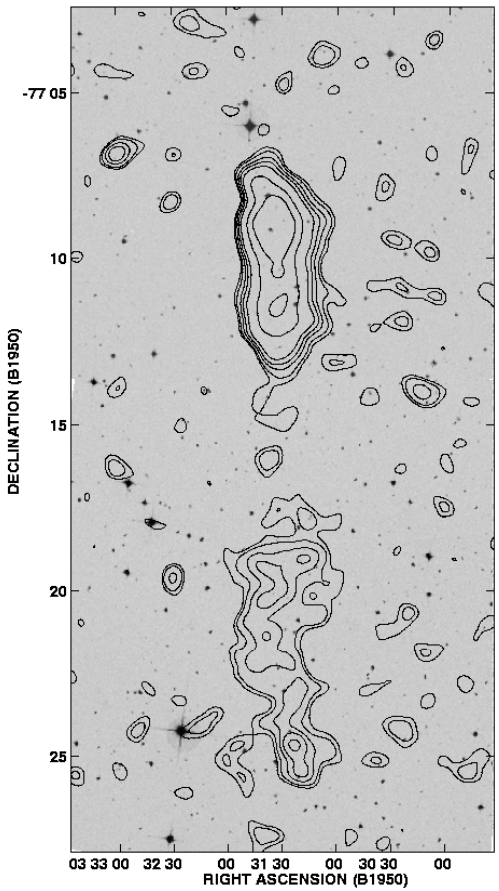


Spectral Index Distribution:
Steep spectrum sources are usually the most distant

843 MHz: Mostly very distant radio galaxies - 80% of sources stronger than 50 mJy have z >0.7

(SUMSS Survey; Mauch et al. 2003)

A complete sample of Mpc-sized double radio galaxies from SUMSS



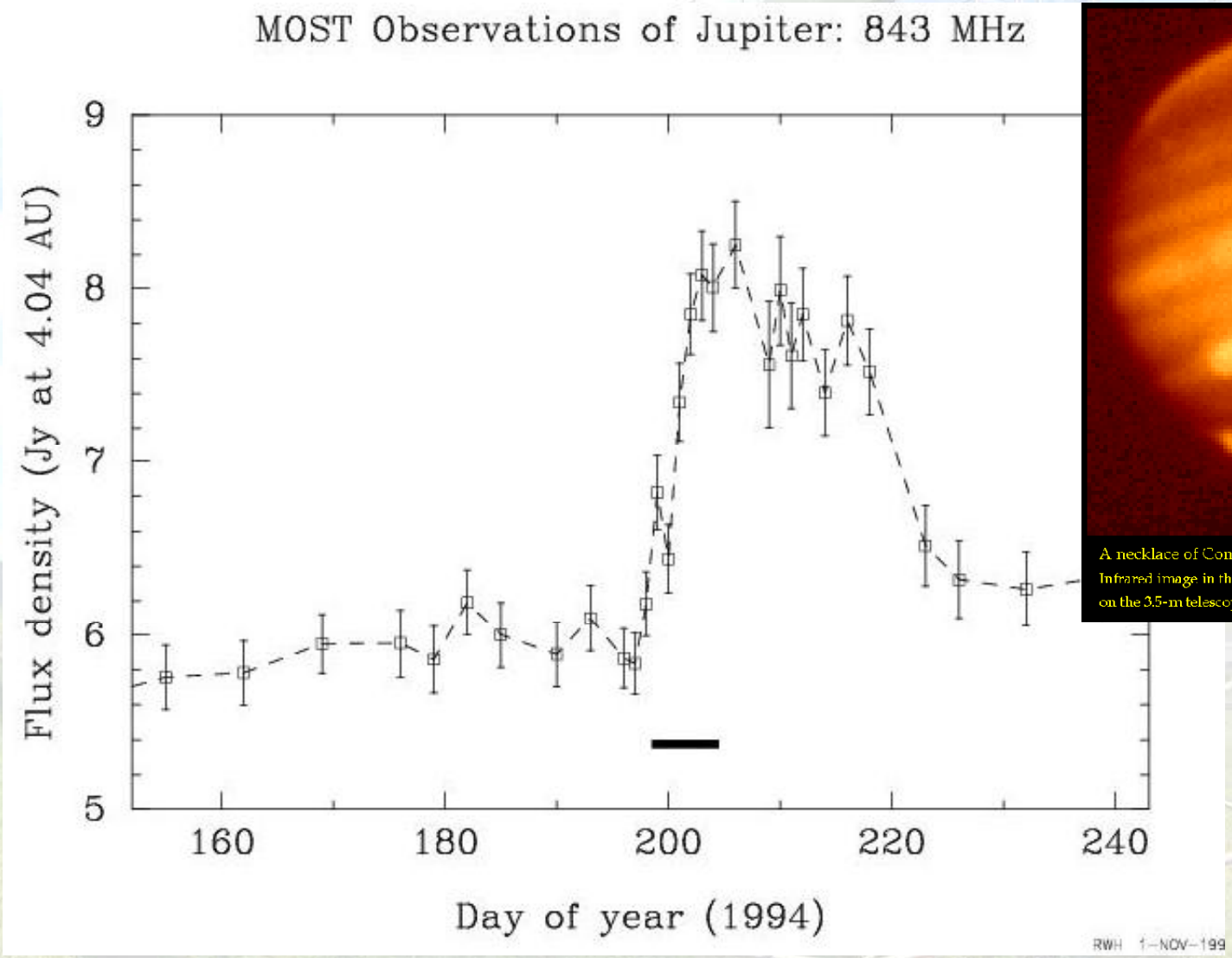
(Saripalli et al. 2005)

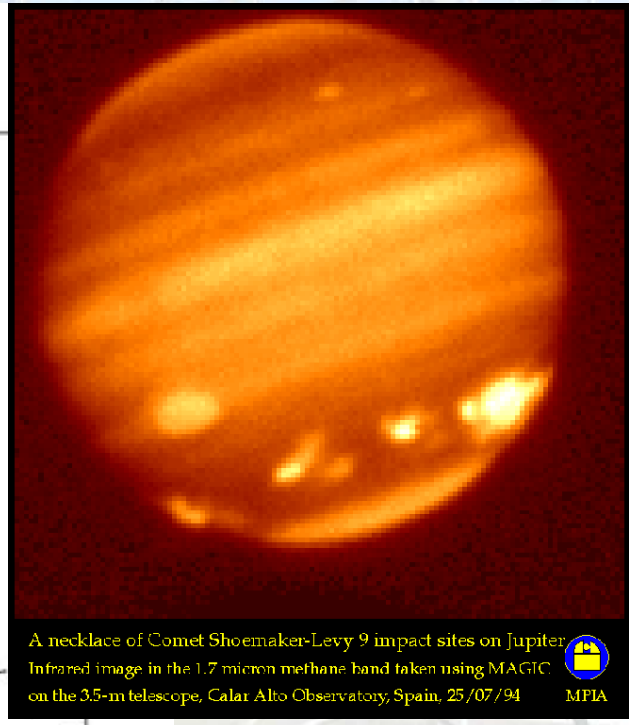
SGRS J0331-7710: Largest-known southern radio galaxy, z = 0.146, projected linear size = 2.67 Mpc

Giant radio galaxies (sizes > 0.7 Mpc) represent the last stage of radio galaxy evolution. They are very rare.

1 Mpc = 3.26 million light years or
30.8 million million million kilometres

Jupiter-SL9 comet crash: July 1994





Galactic interstellar medium (ISM) & studies of SNRs and HII regions

- Current census 265 SNRS – sample incomplete for both young & evolved remnants.
- Galactic Plane survey for $|b| \leq 10°$, 125° in longitude. Large SNRs are missing?
- Current strategies – correlation of MOST (843 MHz) & mid-infrared (8μm) images to separate HII regions & SNRs. Look for ionisation sources for WIM & energy sources for HI shells.

* WIM = warm ionized medium

Galactic Plane (G312.0+0.0)
843 MHz (blue) and 8 μm (red)

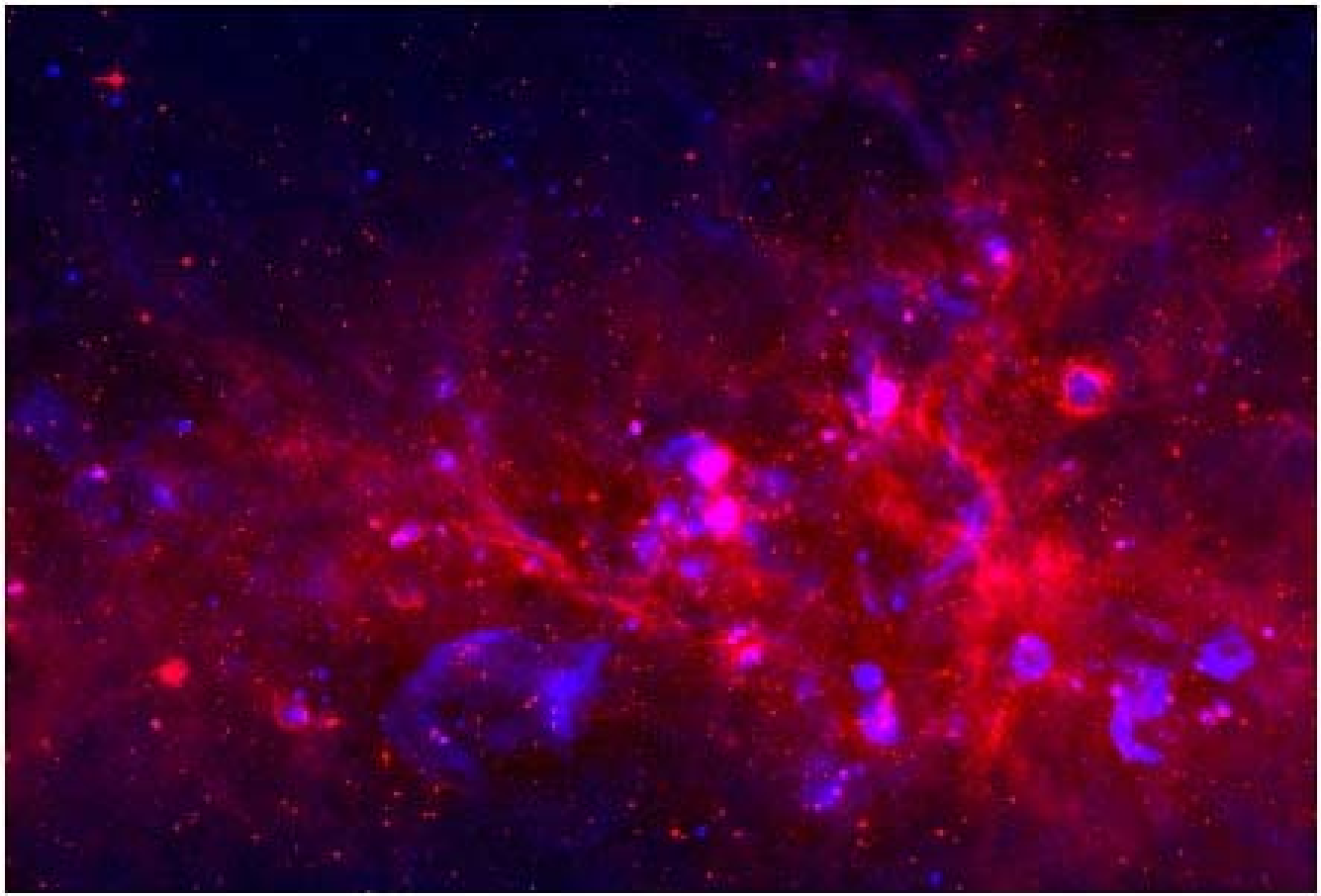
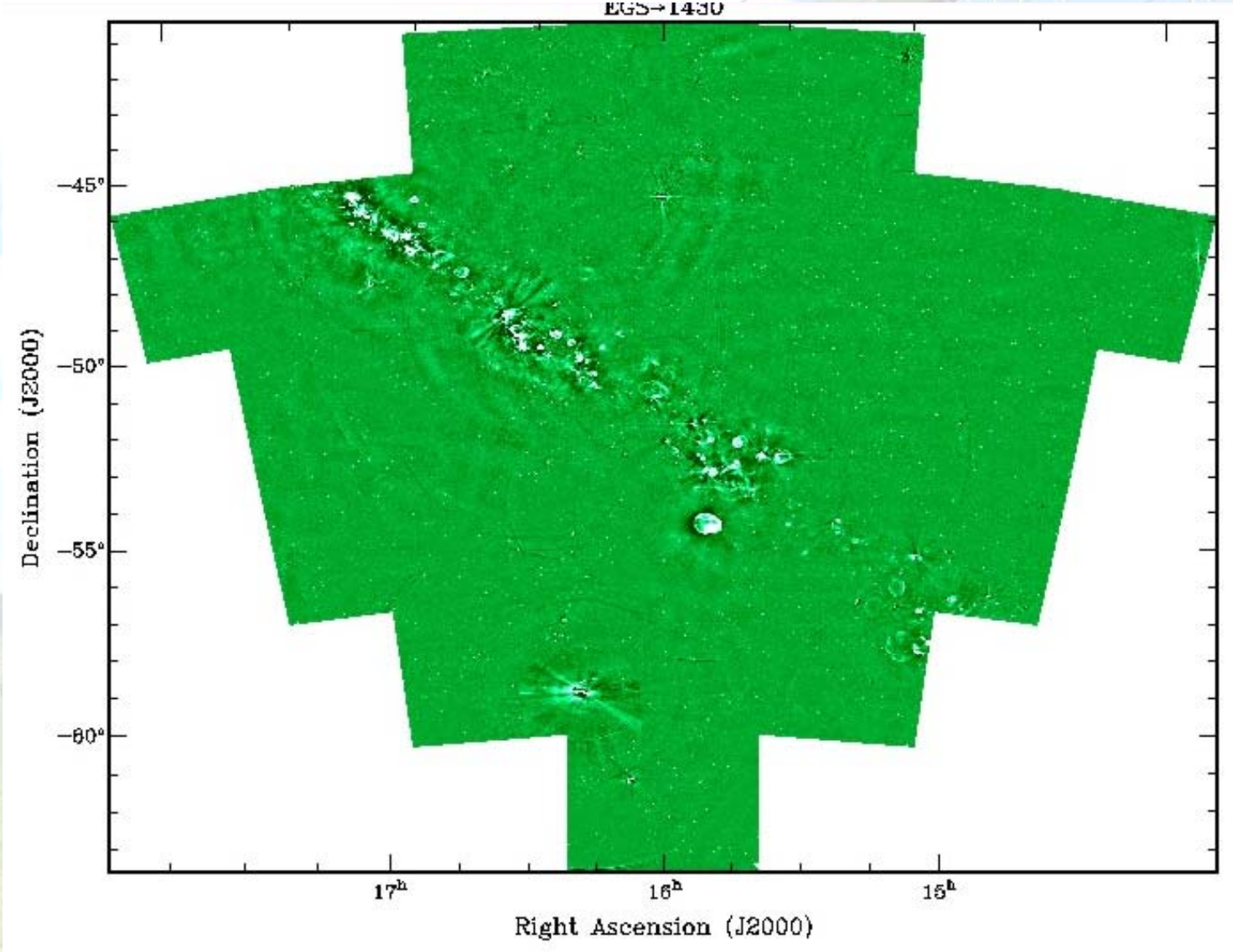


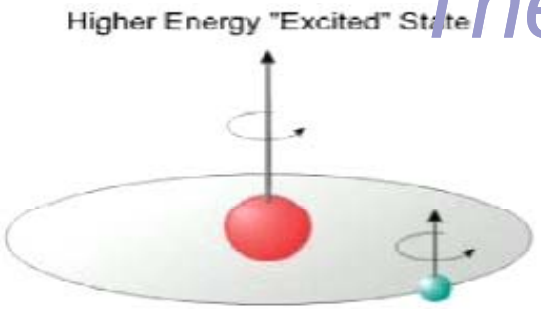
Image 3deg x 2deg

Galactic Plane - complex emission regions

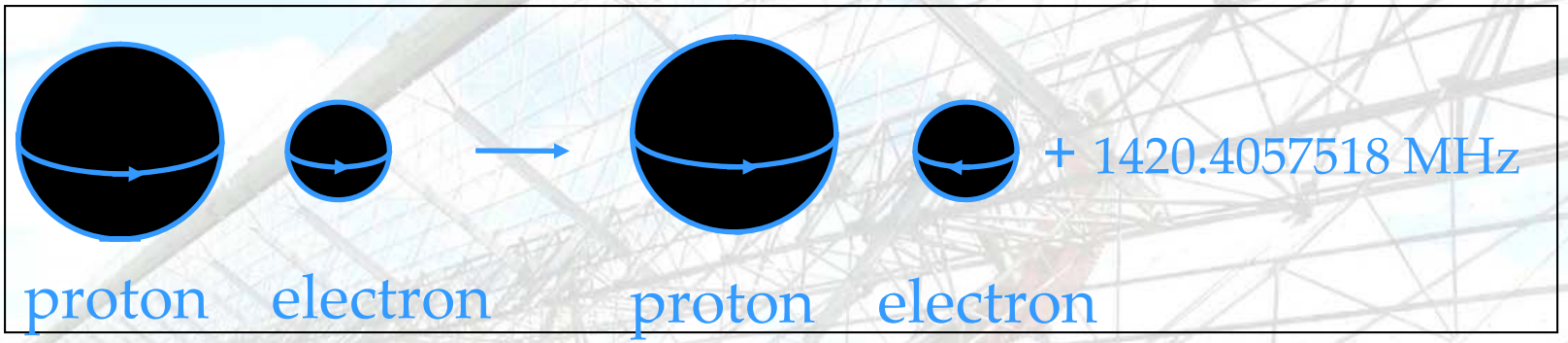


MOST image:
G329.0+0.0
(400 sq deg)

The 21cm HI emission line



A powerful way to look at galaxies and the effects of their interactions is by observing neutral hydrogen with a radio telescope



Very rare event (1 event per atom every 11 million years), but there is a lot of hydrogen in the Universe!

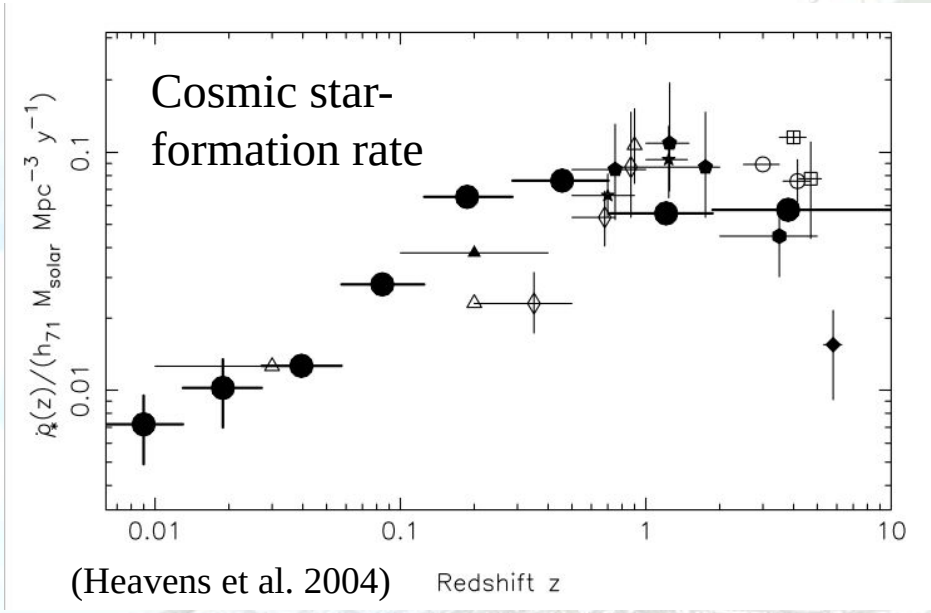
Speed of light

$$\lambda = \frac{c}{\nu} = 21 \text{ cm}$$

ν ← frequency

radio band!

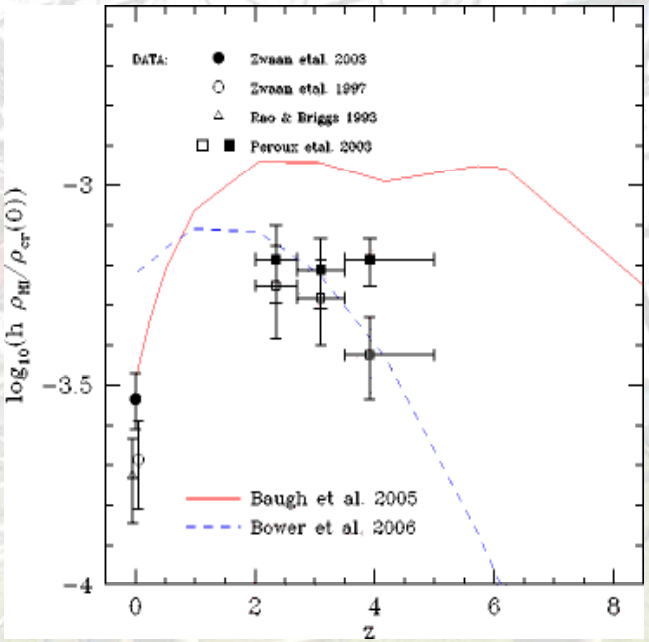
1. How does a galaxy accrete gas?



(Heavens et al. 2004)

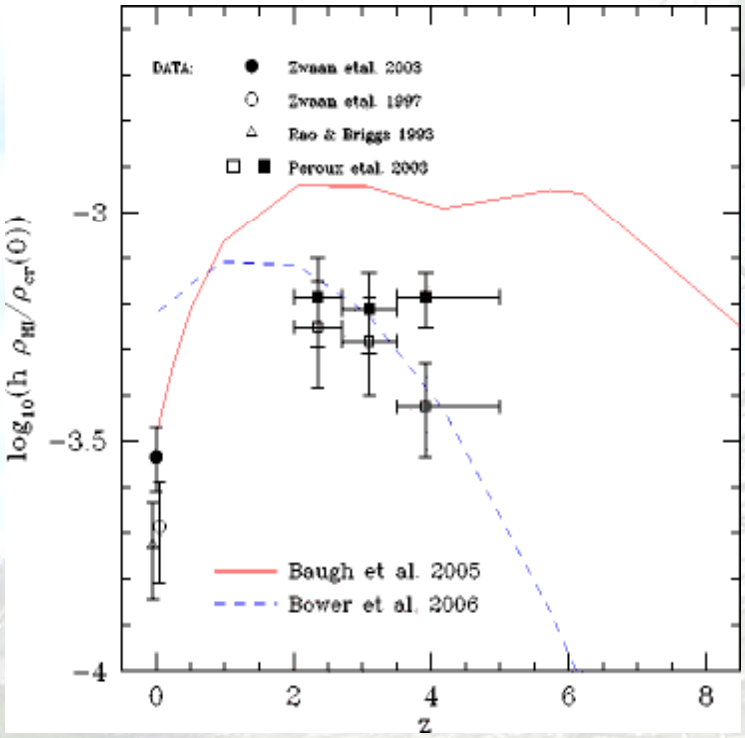
Reasonable idea of the *cosmic star-formation history,* but know almost nothing about how (and when) *the gas is assembled into galaxies.*

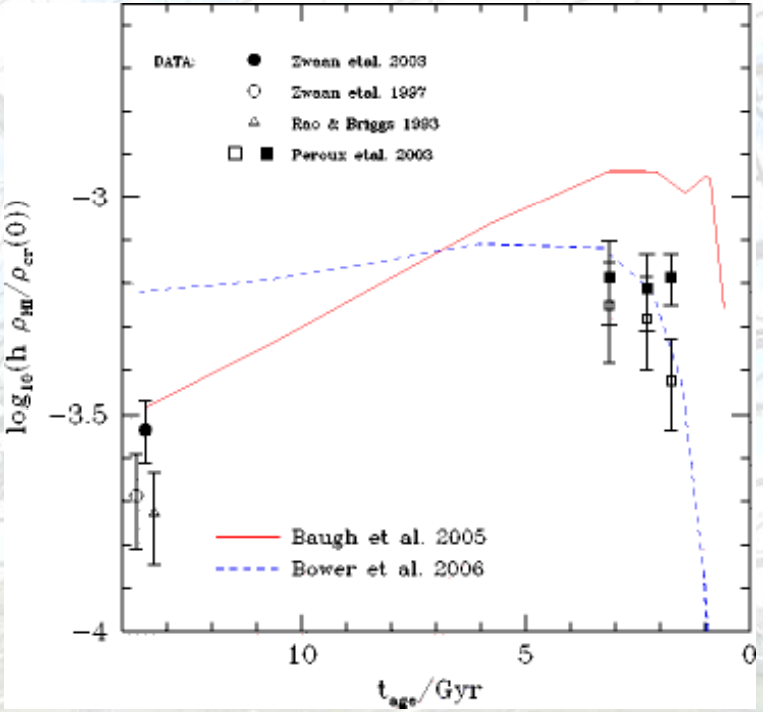
At present, there are few observations to test the predictions for the mass-assembly history of galaxies.



(Johnston et al. 2008)

70% of cosmic time not tested

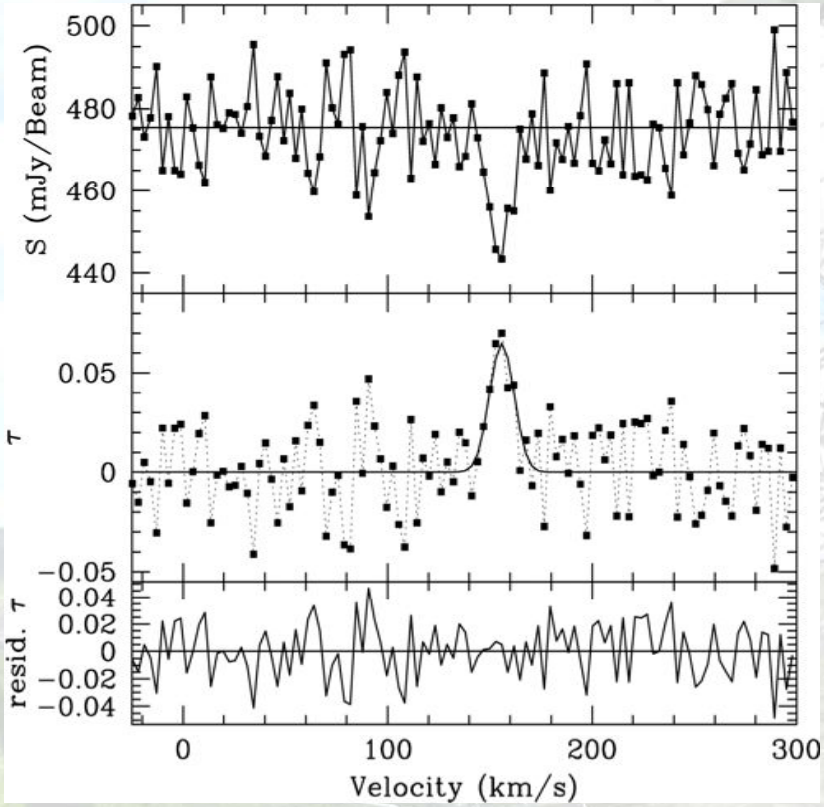




Redshift evolution of the neutral hydrogen (HI) mass density.

Time evolution of the neutral hydrogen (HI) mass density

Blind HI absorption survey planned

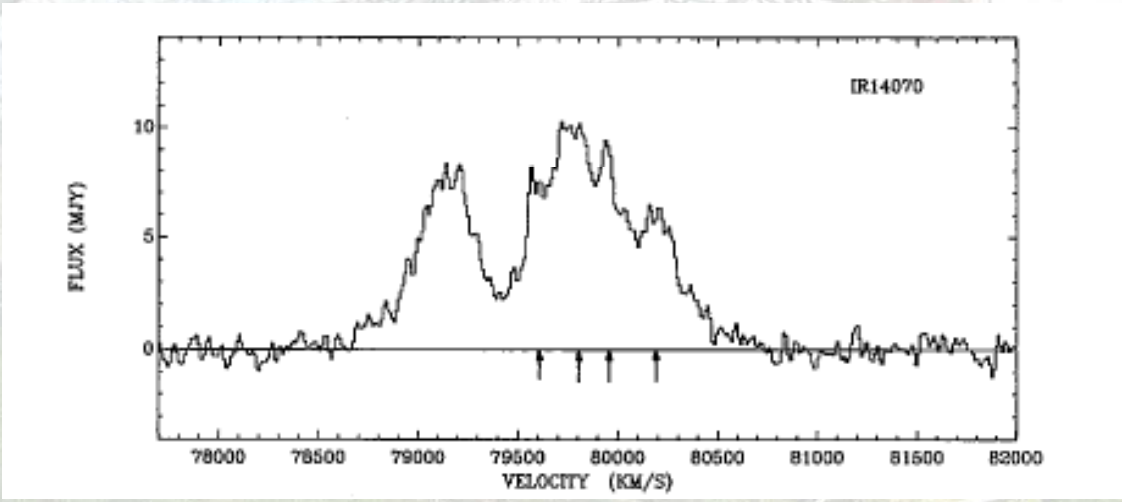


Lane et al. 2001 (z = 0.436 galaxy)

- Radio surveys very sensitive to cold neutral hydrogen (T<200K)
- 80% radio sources have z >0.7
- 0.6% chance a source will have detectable HI absorption in our redshift band
- Need to observe 10,000 sources to get sample of ~60
- Typically 20 sources strong enough per field - survey about 2400 sq deg

2. OH megamasers in starburst galaxies

- OH - hydroxyl molecule, masing is stimulated emission
- OH megamasers found in starburst galaxies, often the result of galaxy mergers
- IRAS 14070+0525 most distant OH megamaser to date at z = 0.265 (883 Mpc)

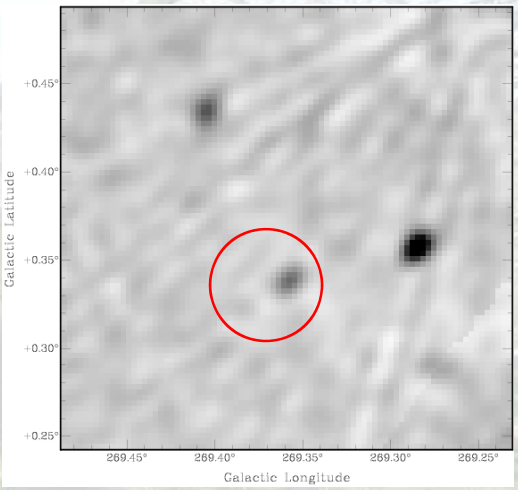


Baan et al. (1992)

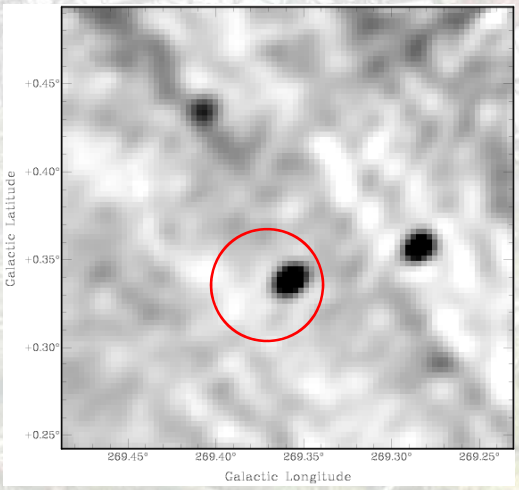
3. Transients & variable sources

- Molonglo has long history of searches & dedicated observations of transient sources
- Pulsars & interstellar scintillation well known
- Unexpected transients & variables largely unexplored

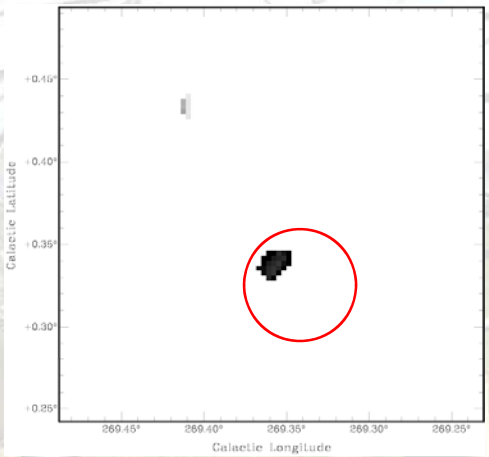
- A new transient from the Molonglo Telescope



Epoch 1



Epoch 2



Quotient map

4. Cosmic Magnetism

Magnetism is crucial for :

Cloud collapse & star formation

Outflows from stars

Gas turbulence

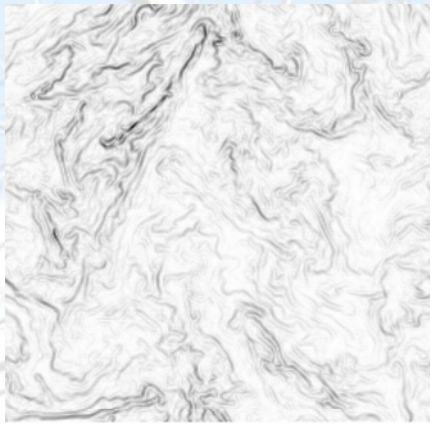
Supernova remnants

Acceleration & propagation
of cosmic rays

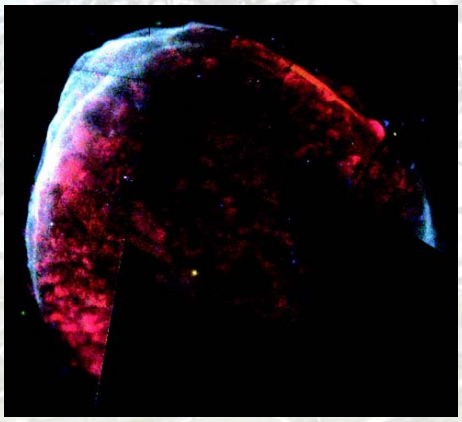
Heating in galaxy clusters

Jets from galactic nuclei

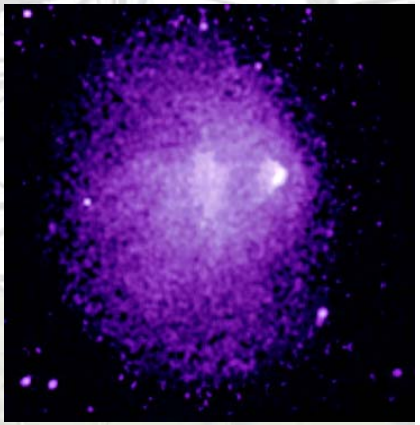
Proplyd in Orion



MHD turbulence



SN 1006

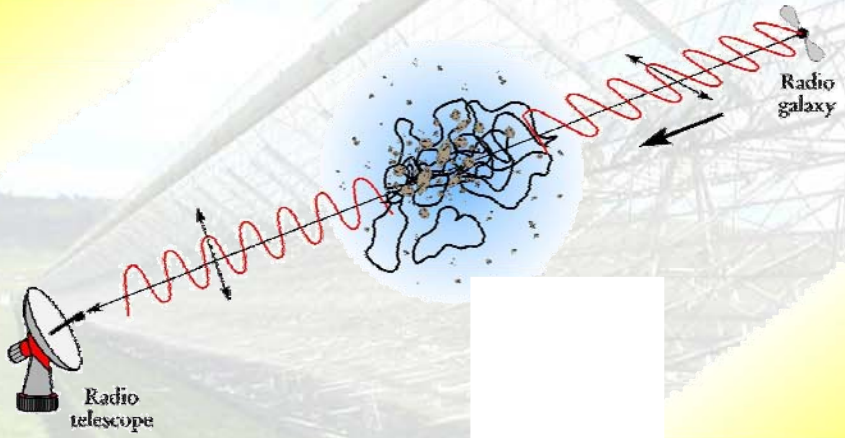


Merger in gal. cluster

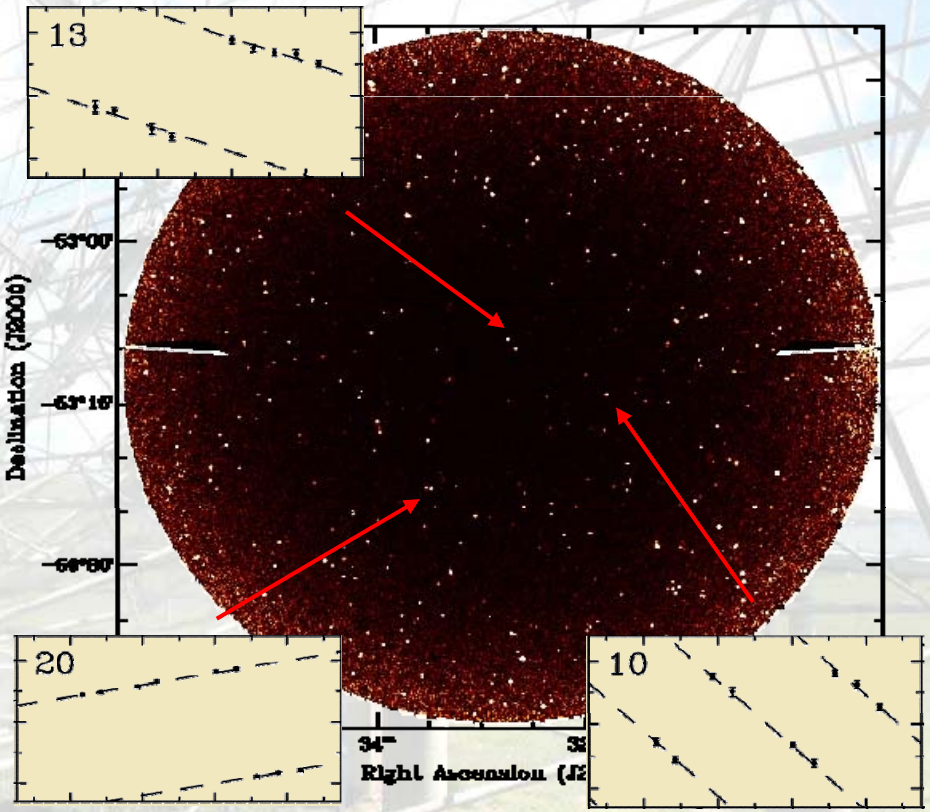
Magnetism is one of the fundamental forces in Nature, but its role and origin is largely unknown !

The Magnetic Milky Way

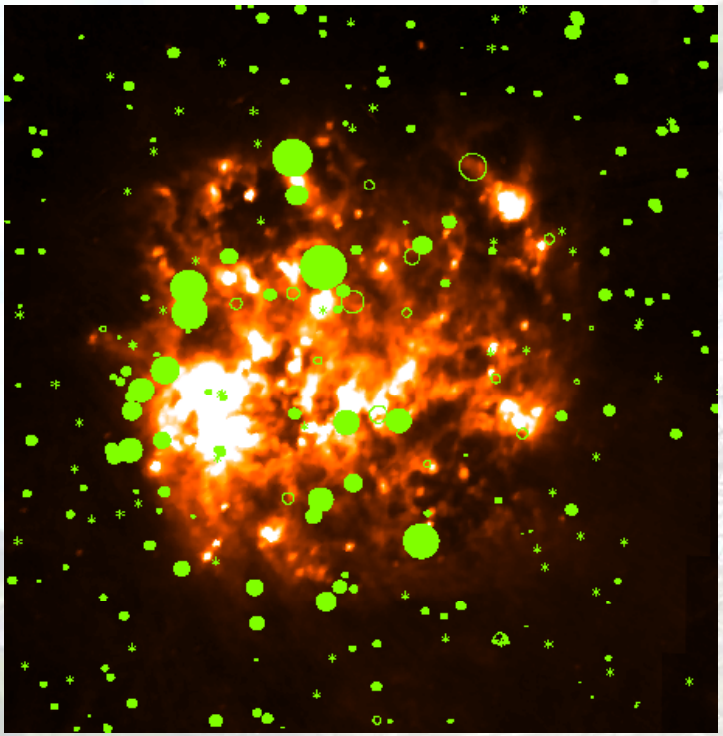
- Mapping the Milky Way's magnetic field probes the creation process
- SKAMP will produce Faraday rotation data for 20,000 background galaxies to give a 3D view of our Galaxy's magnetism



Faraday Rotation



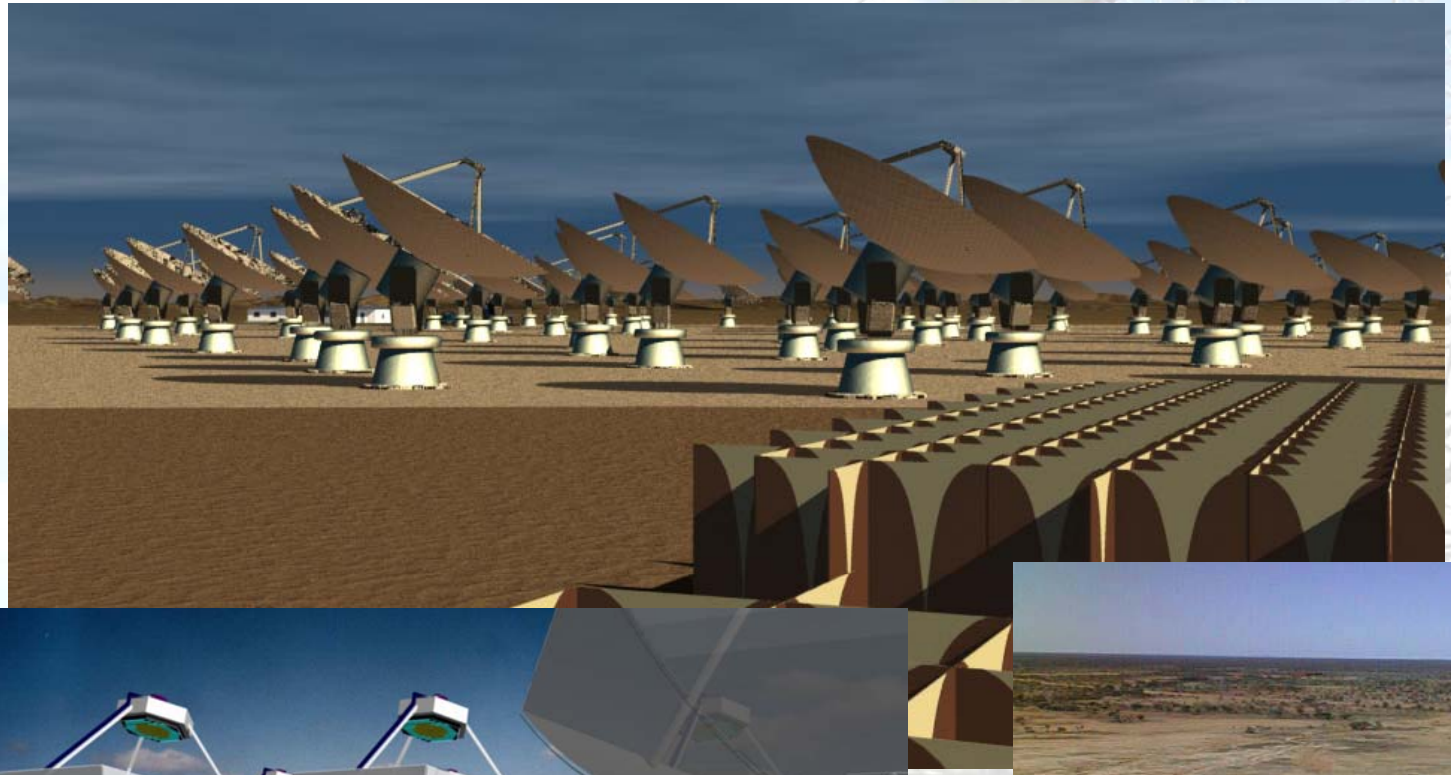
Magnetism study of a nearby galaxy the Large Magellanic Cloud



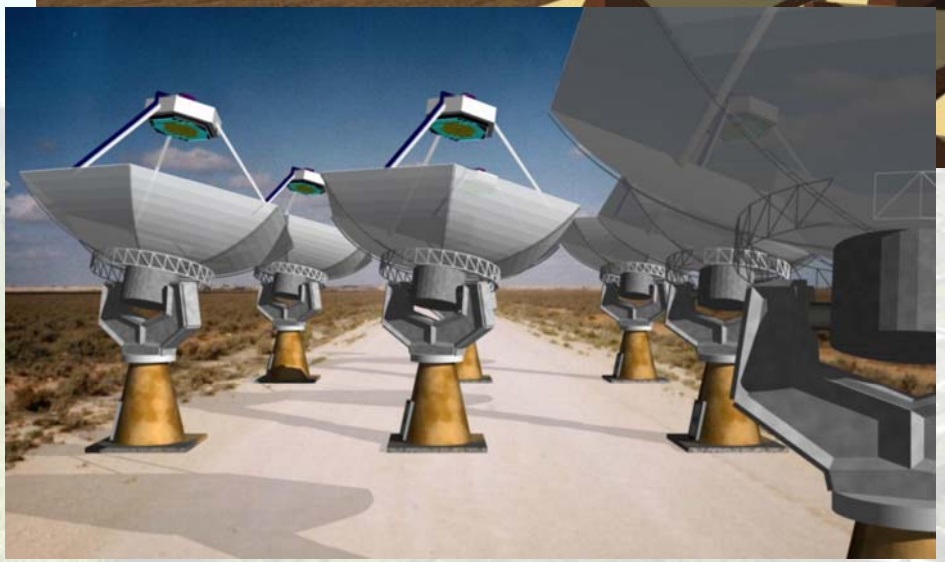
Gaensler et al (2004)

- 300 observations of Rotation Measures against background polarised sources
- Most detailed map of another galaxy's magnetic field
- Surprise result - ordered magnetic field even though galaxy being ripped apart by Milky Way

What about the future? SKA



A telescope for the next 50 yrs



Australian site - WA

A concise history of the Universe