The SKA Molonglo Prototype (SKAMP) Project
MNRF Symposium Report, June 2005

SKA Molonglo Prototype Project (SKAMP)

- Alternative technology to achieve wide-field imaging for SKA – hybrid concept using cylindrical reflectors.
- Provides 1% collecting area of SKA
- Project Goal: complete signal pathway – 2:1 dual polarisation line feed; no cryogenics; wideband digital signal processing; FX correlator.
- Features: wide field of view, imaging, polarisation, spectral line capability, RFI mitigation (adaptive noise cancellation).
- Strategy: parallel 3-stage re-development of MOST
- Science Outcomes: new low-frequency spectral line facility – pathfinder science

SKAMP Team

University of Sydney

- Anne Green
- Duncan Campbell-Wilson
- Adrian Blake
- Tim Adams
- Martin Leung
- Sergey Vinogradov
- Daniel Mitchell
- Elaine Sadler
- ~4 site Technical Officers

CSIRO – ATNF & ICT

- Michael Kesteven
- Tony Sweetnam
- John Bunton
- Frank Briggs
- John Kot

Argus Technologies

- Bevan Jones
- Martin Owen
- Peter Liversidge

Molonglo Observatory Synthesis Telescope (MOST)

Photo: G. Warr

Current Parameters for MOST

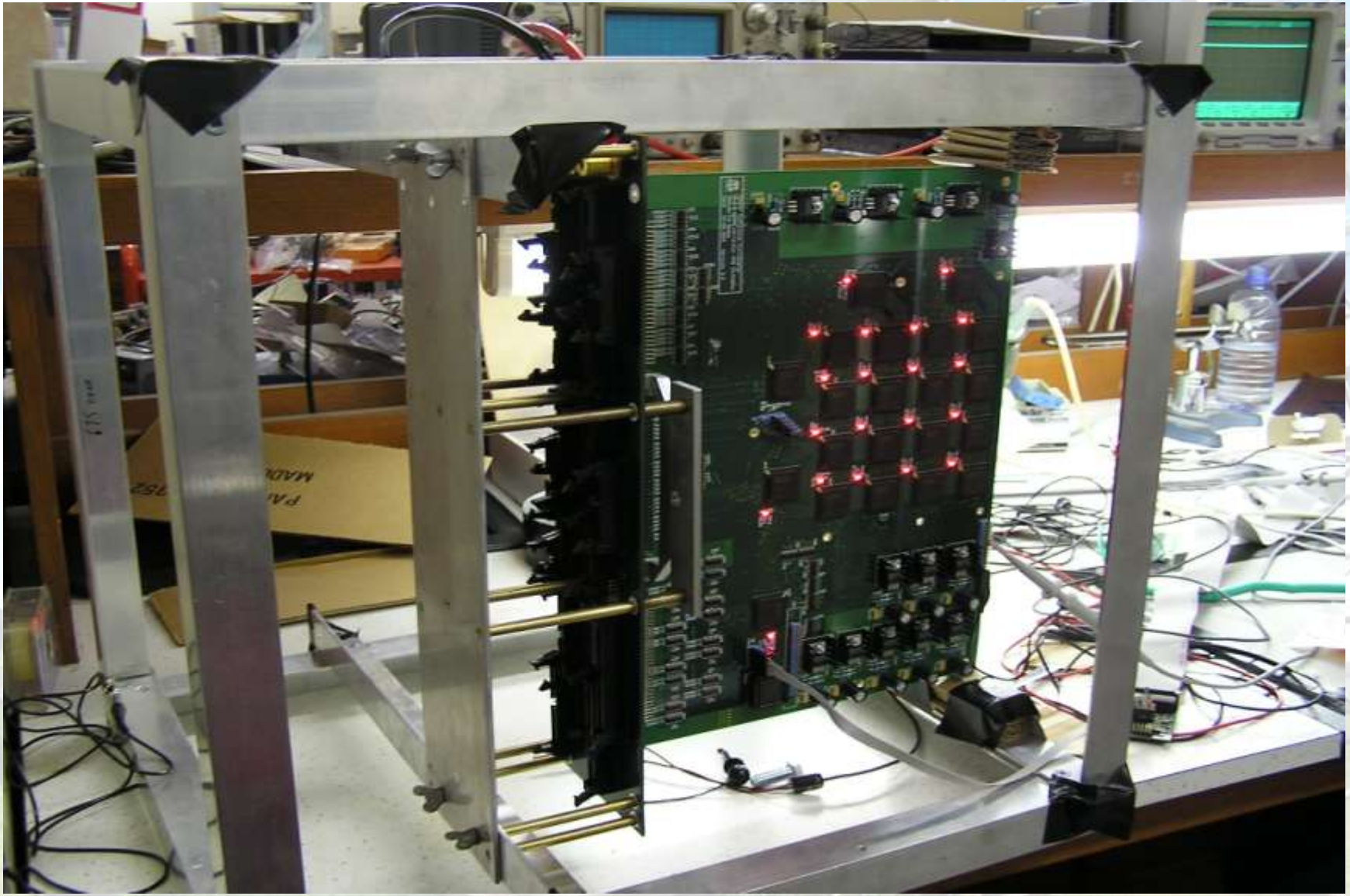
- Single frequency - 843 MHz continuum
- 3 MHz bandwidth, RHC polarisation
- 43" spatial resolution
- 18,000 sq metres collecting area
- T_{sys} 55K
- Field of view: >5 square degrees
- Sensitivity (7 position switching): 0.8 mJy
- Sensitivity for full 12 hr: 0.3 mJy
- Dynamic range: ~200:1

SKAMP 1 (2004 – 2005)

- Continuum correlator: 96 station, 4.4 MHz bandwidth, 843 MHz central frequency – > 4000 baselines, data rate 1sec
- New electronics based on programmable chips (FPGAs)
- Digital delays & fringe-tracking
- Sensitivity 0.8 mJy (12 hrs for complete synthesis; 7-position switching to gain wide field of view)
- Continuous *uv*-coverage – correlation of inter-arm & between-arm stations to give good image fidelity
- Improved dynamic range expected – visibilities now recorded for each baseline
- Parallel operation with Molonglo Sky Survey (SUMSS) project (observations to be completed within 12 months)

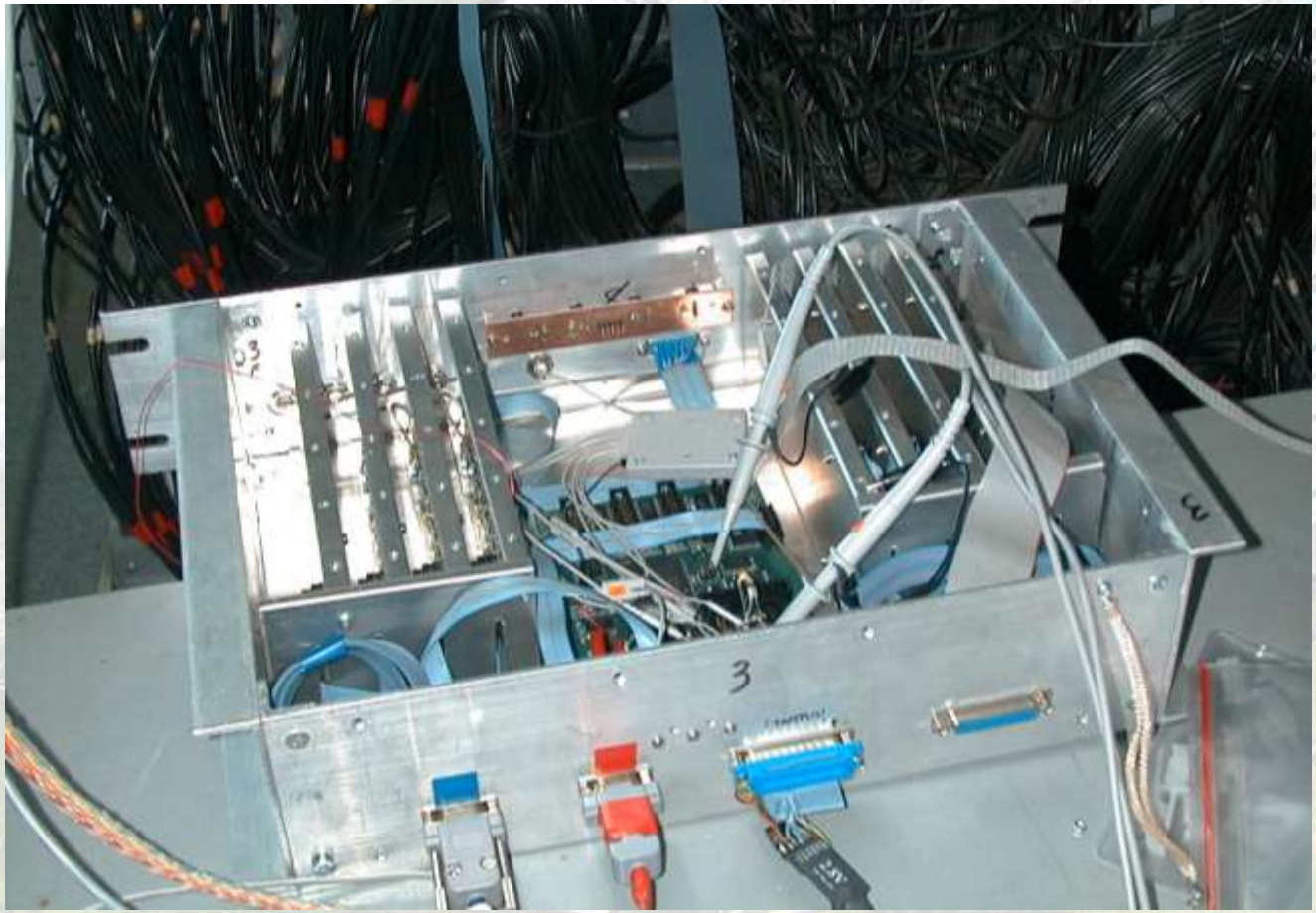
Continuum correlator

- Operational at site
- 96 stations – telescope and reference antennas
- Bandwidth 4.4 MHz
- Integration of complete signal pathway undergoing debugging and commissioning



Tim Adams & John Bunton

12 boards (FPGA-based) for digital delay and phase corrections installed and programmed – testing underway



First Fringes – single baseline & interim correlator

Team:
Green
Campbell-Wilson
Kesteven
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*Chippendale
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*Mitchell
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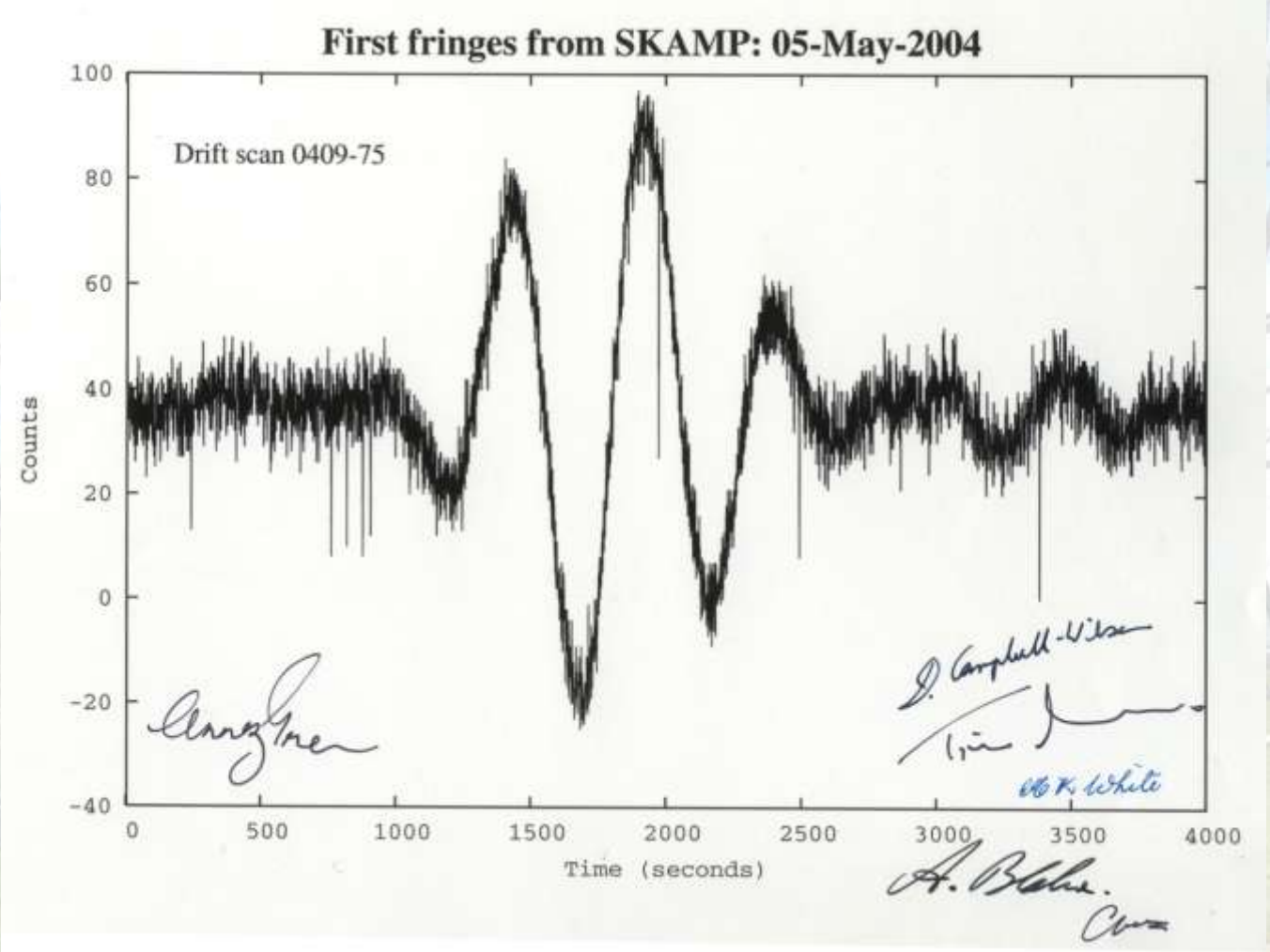
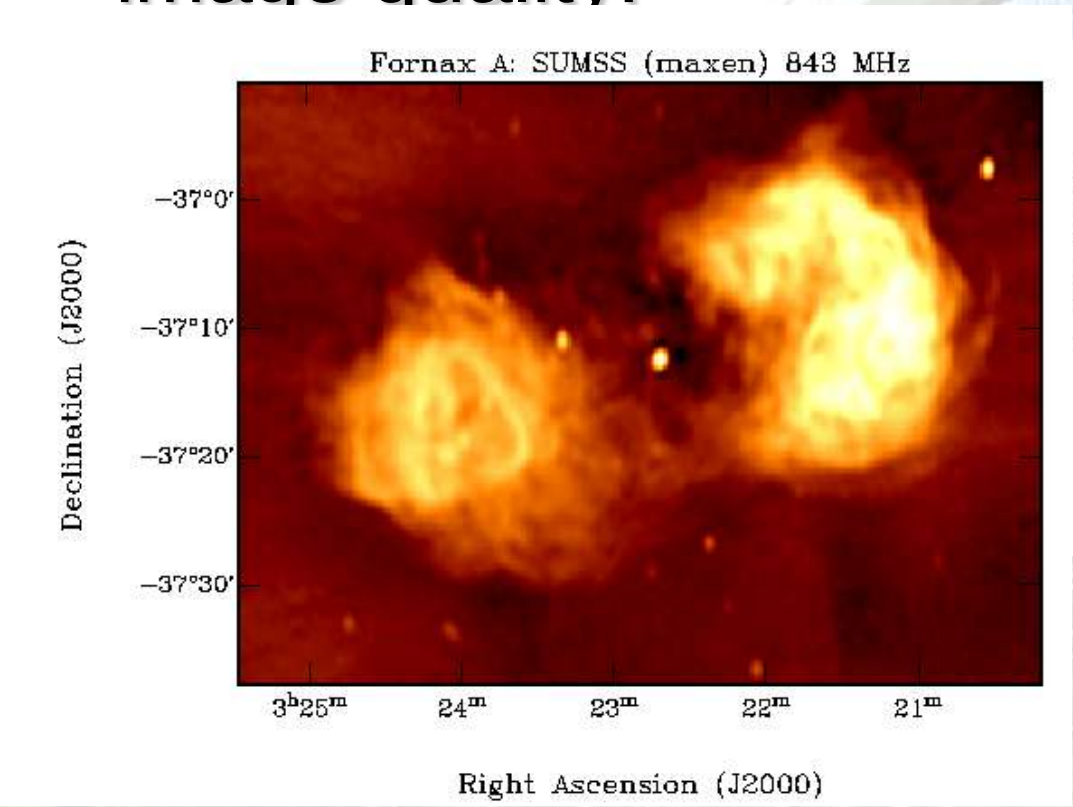
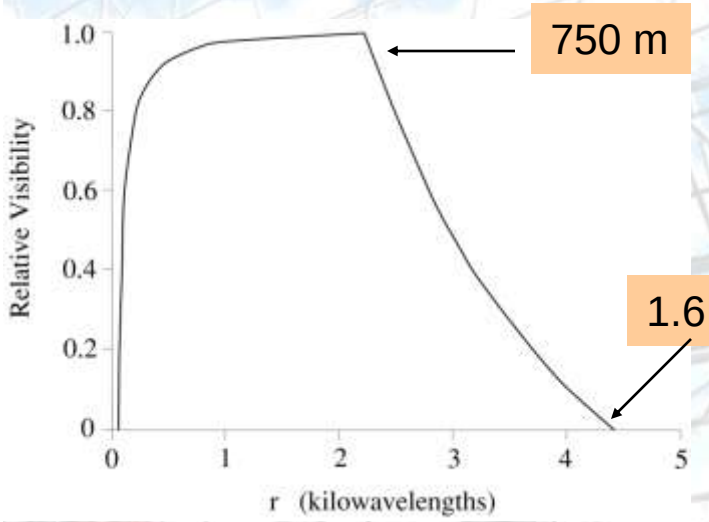
Sadler



Continuous *uv* coverage gives excellent image quality:

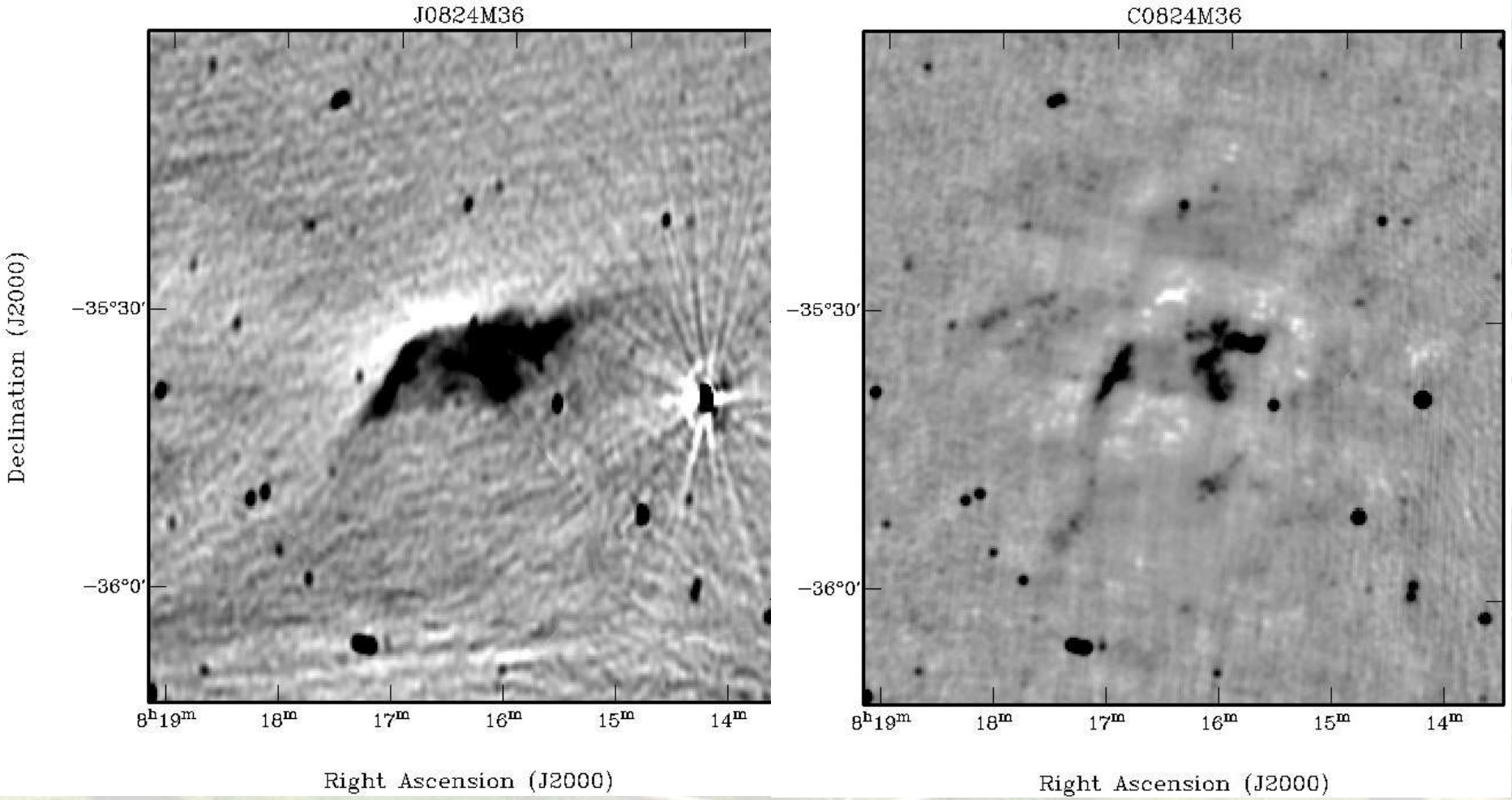




(Bock et al. 1999)

- Continuous uv coverage from 15 m to 1.6 km in 12 hr complete synthesis

Example of high image fidelity resulting from good *uv*-coverage

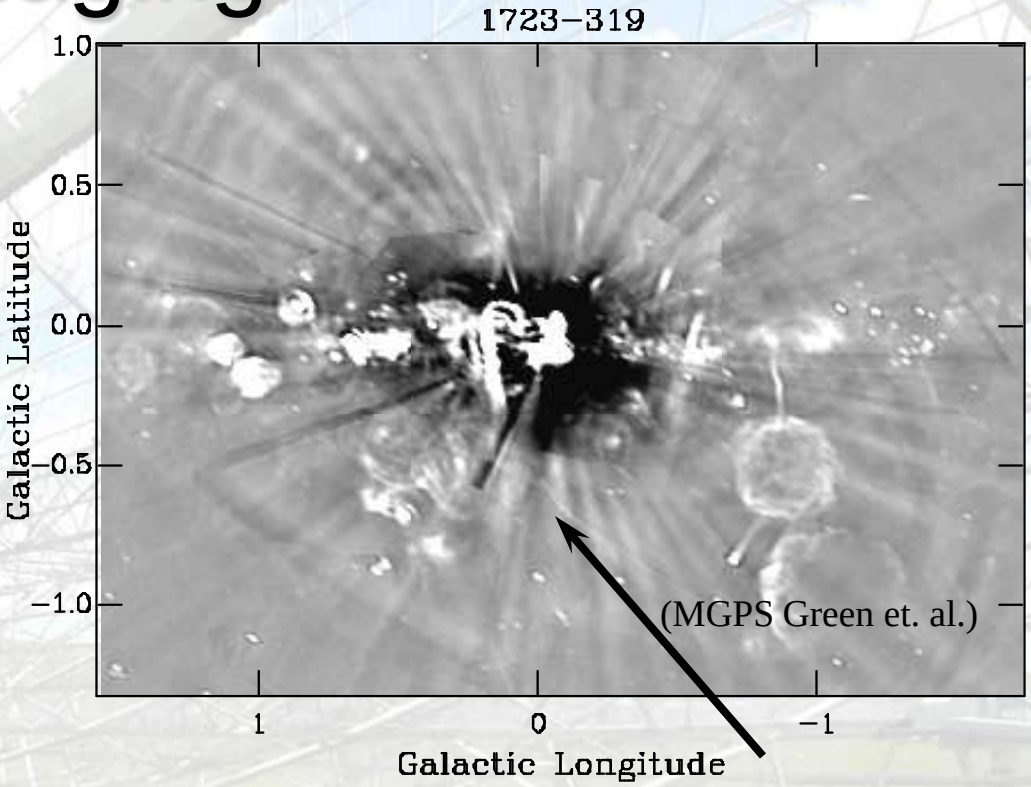


Goal: high-dynamic range continuum imaging

StageI correlator will allow self-calibration strategies for MOST

Current MOST imaging dynamic range is 100-200:1 (similar to intrinsic dynamic range of VLA)

Self-calibration on VLA enables imaging dynamic ranges of more than 10^5:1

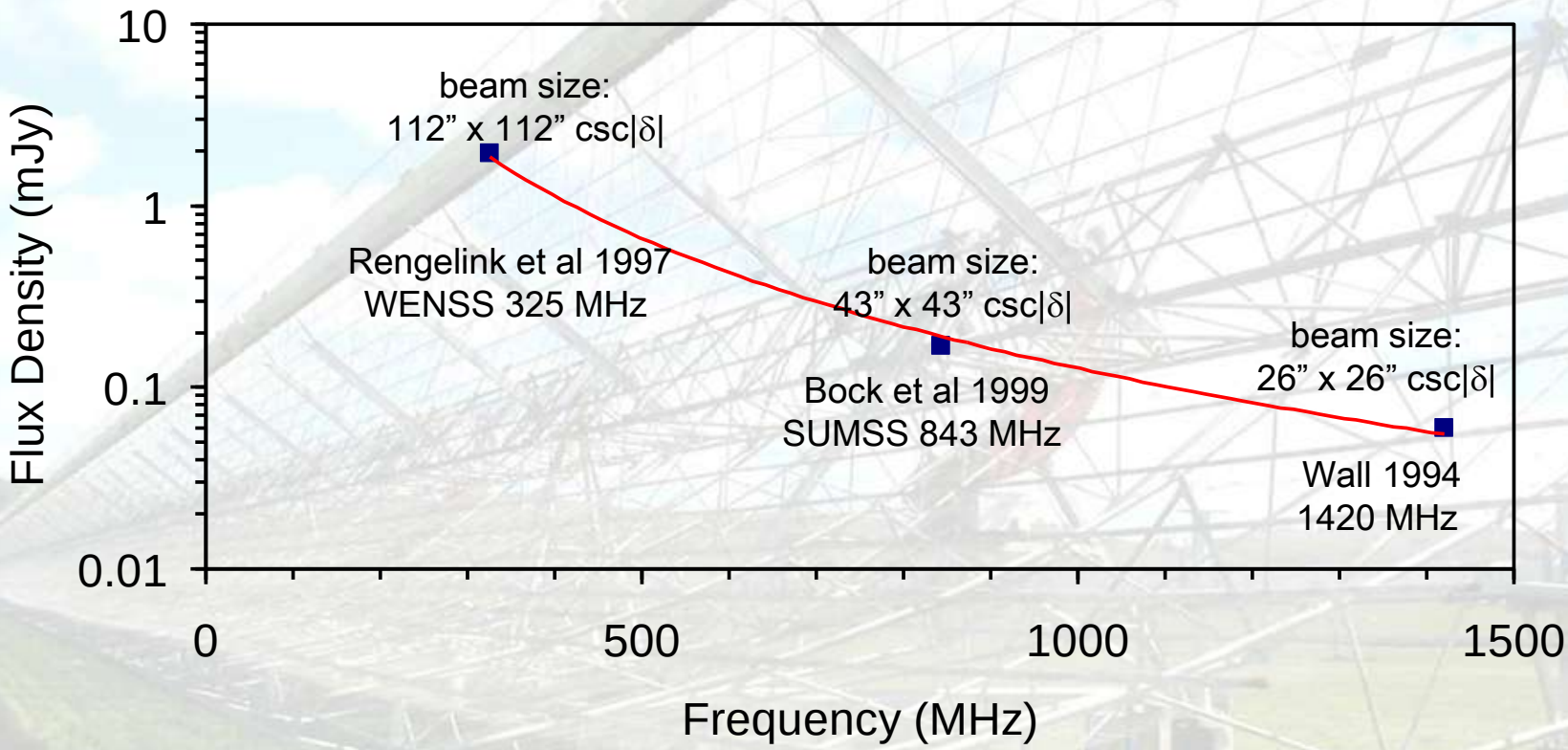


Current dynamic range of MOST limits imaging of faint sources, such as filaments of supernova remnants, near bright sources like the Galactic Centre.

SKAMP 2 (2005 – 2006)

- Spectral-line capability: 30 MHz BW from 830 - 860 MHz with 2048 channels via FX correlator.
- Existing front end retained – 96 stations allow more than 4000 independent baselines, highly redundant
- Unchanged Tsys and angular resolution
- Optic fibre distribution network designed – spools in concrete tank to equalise lengths; trenching started
- Field of view 4 square degrees
- Sensitivity for 12 hrs observation: 0.15 mJy
- Confusion limit of 0.12 mJy for 43" resolution
- Spectral line measurements not confusion limited

Molonglo continuum confusion (10 beams/source) at δ = –60°



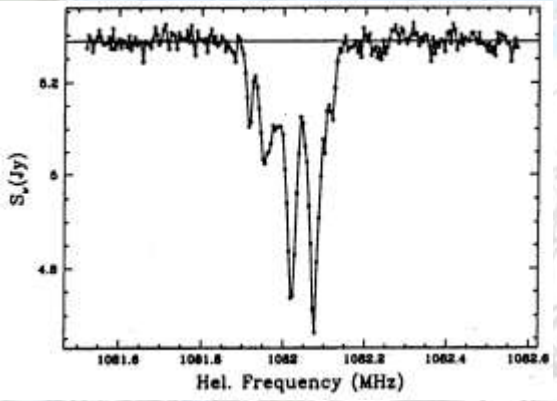
Science with spectral-line capability

Stage 2: 830-860 MHz range and 2048 spectral channel FX correlator enables:

- Measurements of HI absorption at z ~ 0.75 that capitalise on the large collecting area of MOST

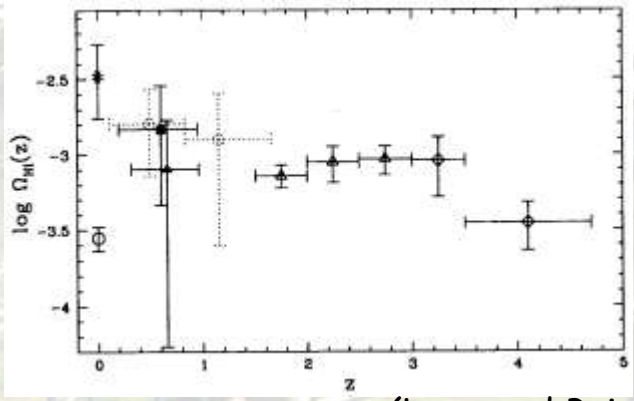
- >10,000 sightlines to search for HI absorption – expect to detect ~50 sources in limited redshift range in 2400 sq deg

- OH megamaser emission surveys at z~1



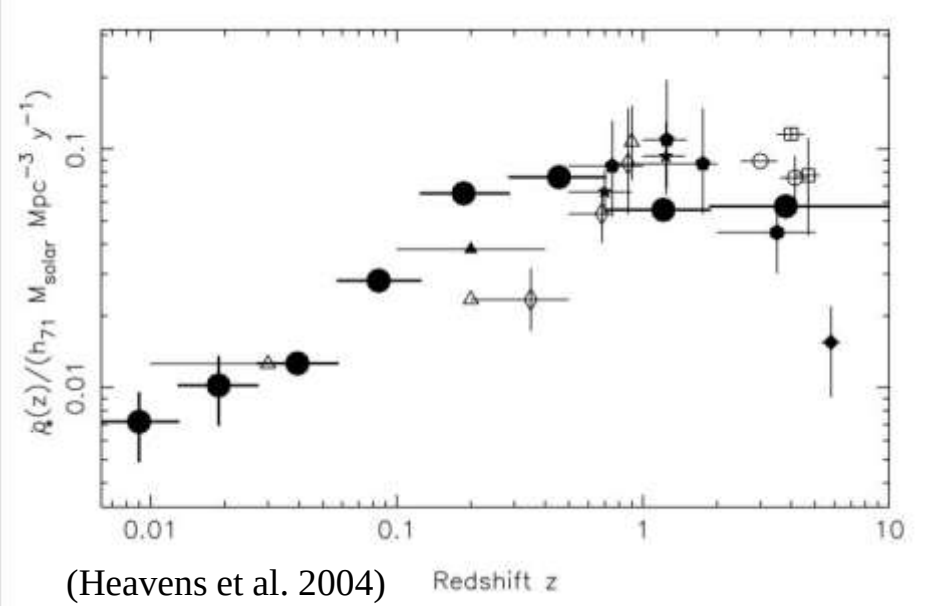
(Lane 2000)

Stage 2: enables Ω_{HI} measurements at z ~ 0.75, where existing results are not well constrained



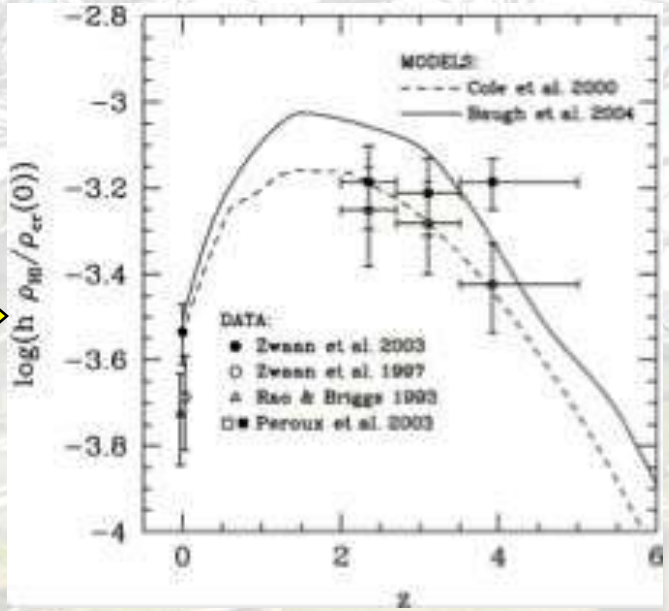
(Lane and Briggs 2001)

Why HI absorption-line studies?



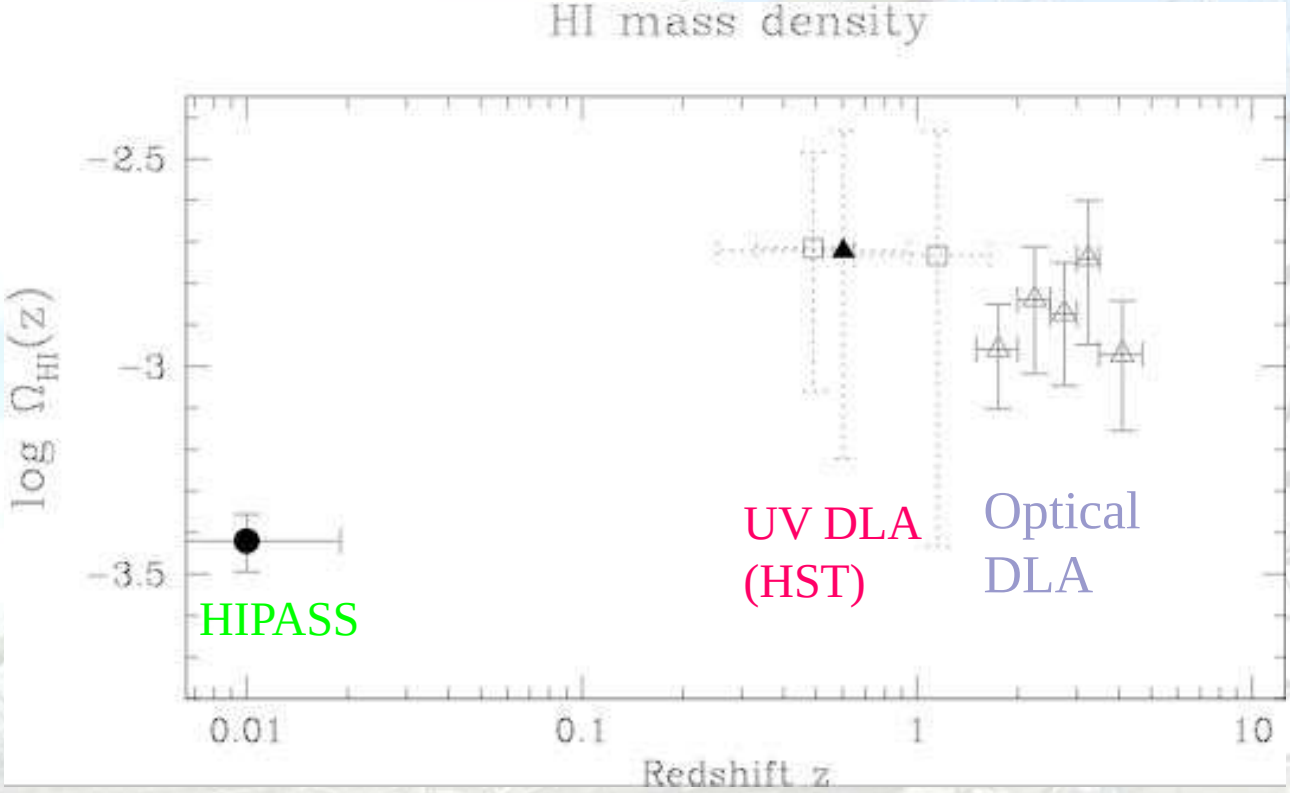
(Heavens et al. 2004)

We now have a reasonable idea of the *cosmic star-formation history*, but know almost nothing about how (and when) *HI is assembled into galaxies.*



Until SKA, HI absorption lines provide the main test of CDM predictions for the mass-assembly history of galaxies.

Looking in more detail …

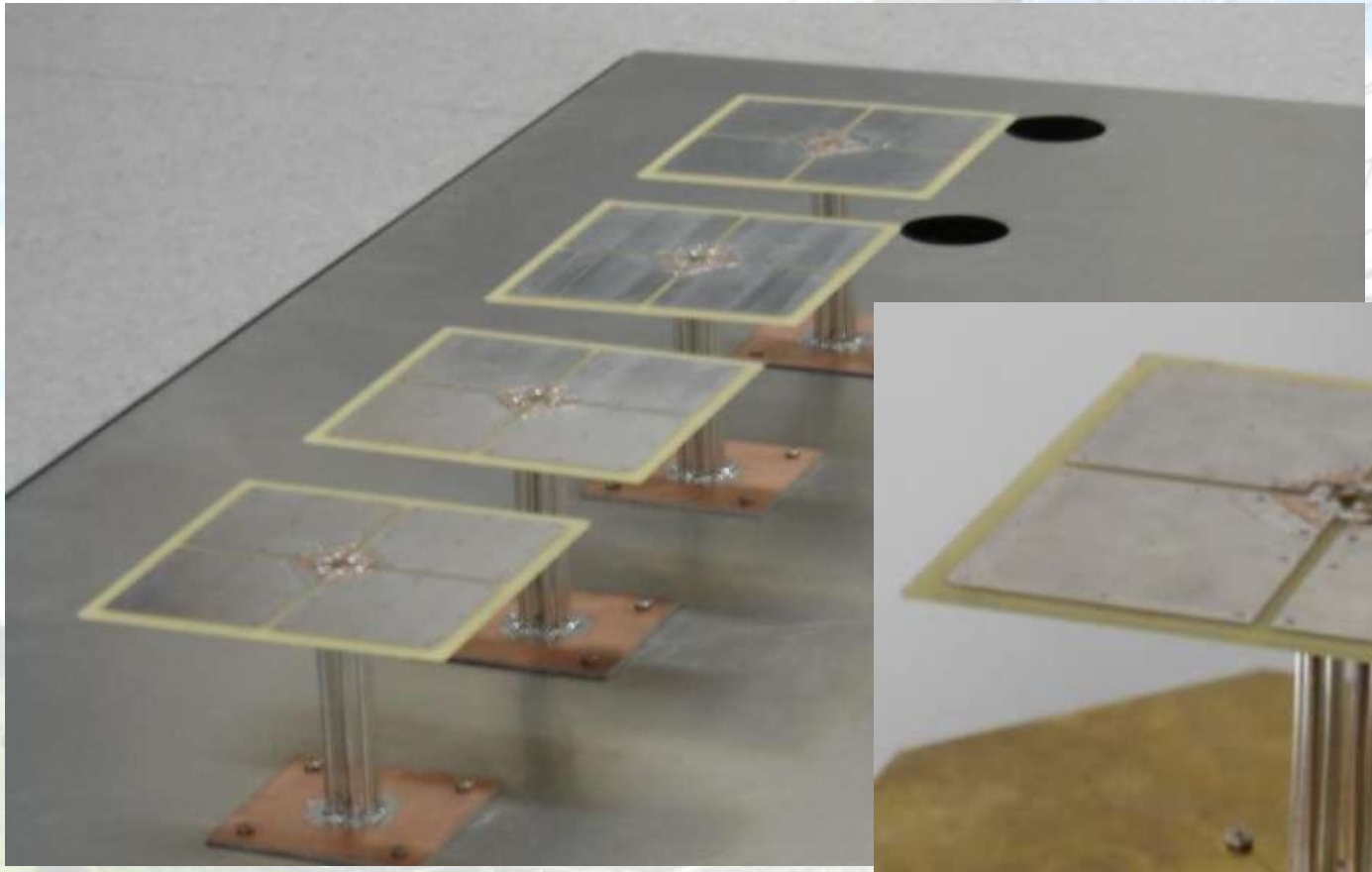


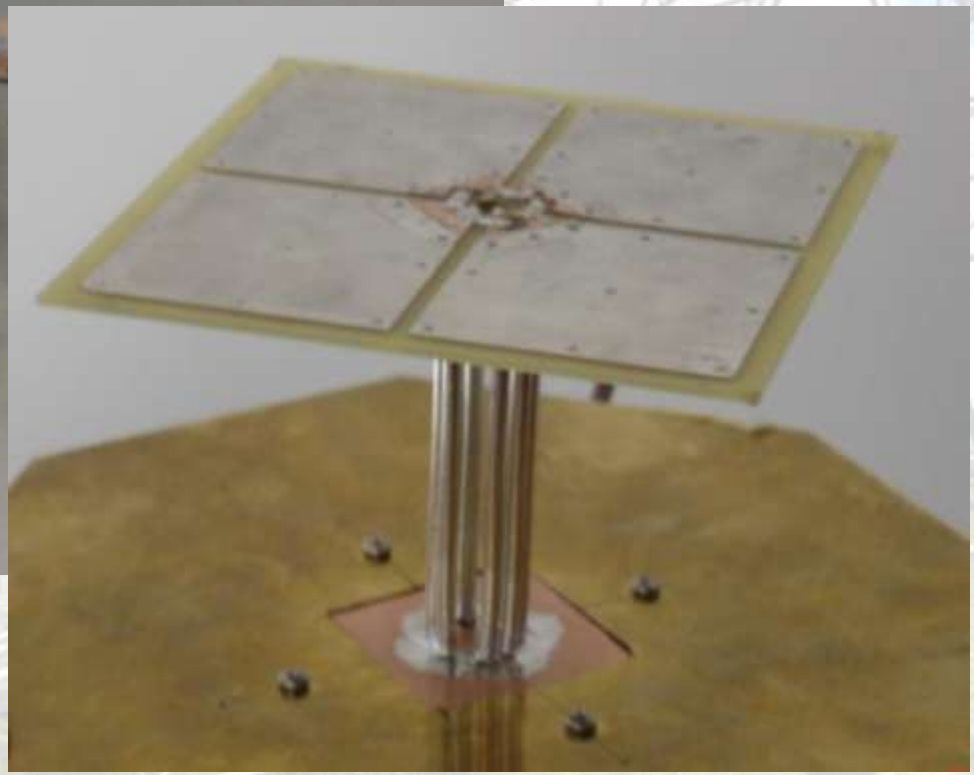
Ground-based optical DLA studies are only possible at z>1.7. At lower z, UV DLA observations with HST are sparse, and analysis complicated by selection effects. *80% of cosmic time is essentially unprobed*

SKAMP 3 (2006 – 2007)

- Dual polarisation feed modelled – ~1% instrumental polarisation from 650-1100 MHz. Surface irregularities to be measured.
- 8-element module of 4-patch antennas (centred on 866 MHz frequency) being manufactured for array test.
- Two-stage beamforming – at least one RF on feedline
- Rapid Prototype Telescope under construction - feed and mesh testing. Spoiler design to minimise baseline ripple.
- Instantaneous bandwidth 100 MHz
- SKAMP 2 correlator to accommodate greater bandwidth
- New mesh will give reduced Tsys of 40K.
- 12 hr sensitivity at 843 MHz ~0.1 mJy. *Confused!*
- Polarisation not confusion limited (assume 5% mean source value).

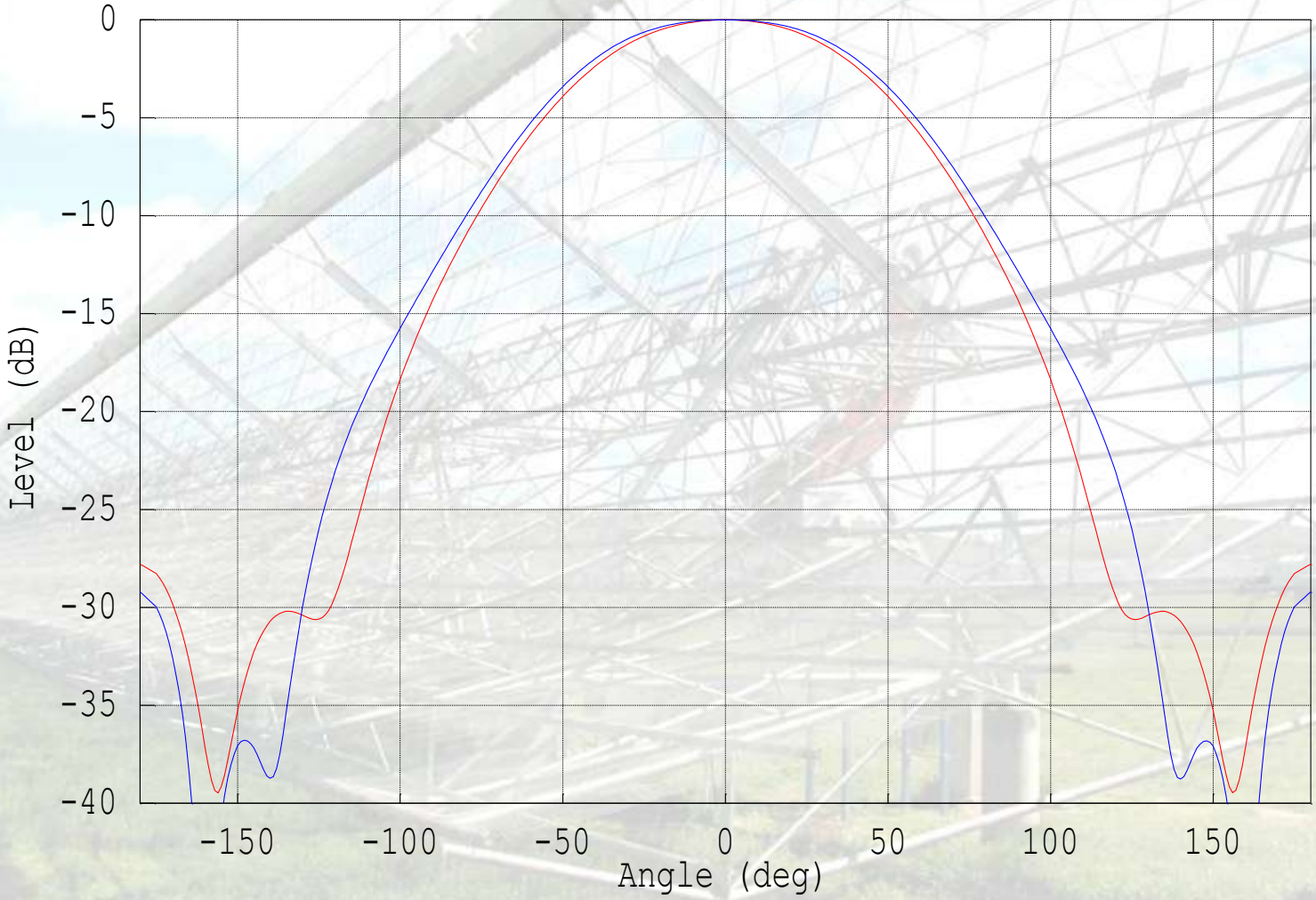
Feed prototype at Argus Technologies





Leung, Jones, Owen

Difference in orthogonal polarisation beam patterns



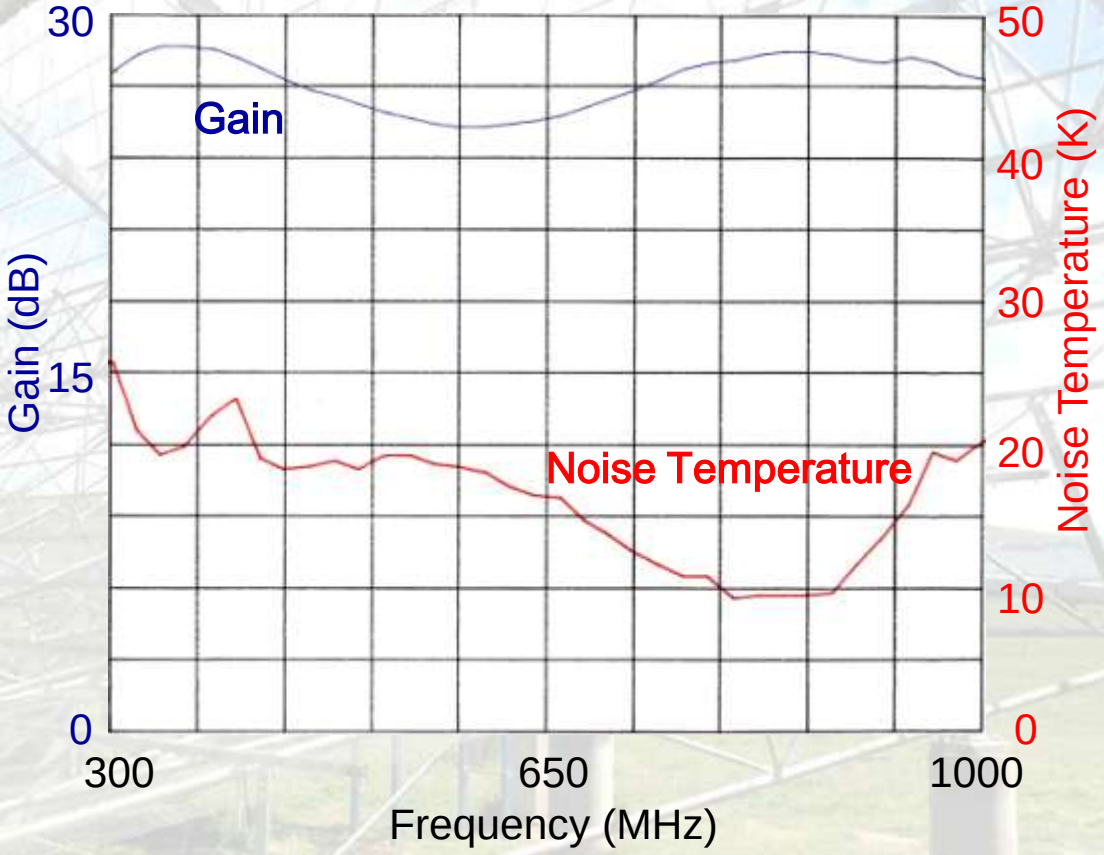
Rapid Prototype Telescope (RPT): construct one 17m station for trials

Spine & supports for arms ready.
Mesh – existing rectangular mesh to be installed & overlaid with new 6mm square mesh.

Wide-band uncooled Low Noise Amplifiers

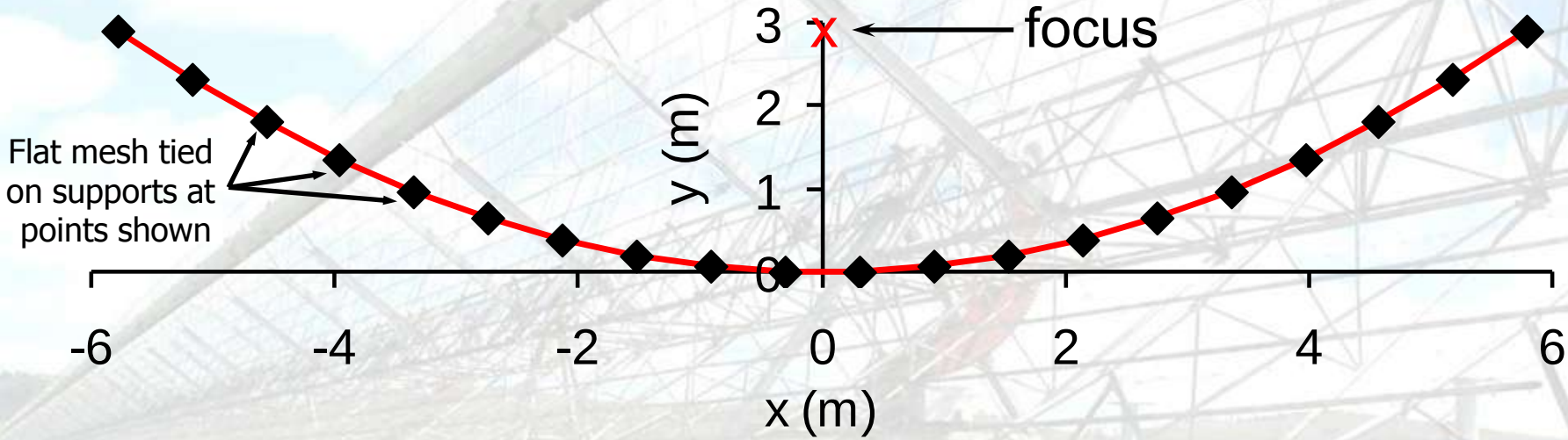
Prototype 300-1000 MHz HEMT based LNA (Ralph Davison)

- ~20K noise temperature
- Ambient temperature operation
- Possible extension to operate 300-1400 MHz
- Design simplified if higher input impedance from antenna tolerated (designed for 50Ω input impedance)
- Mass production (8000 units) requires simple assembly design



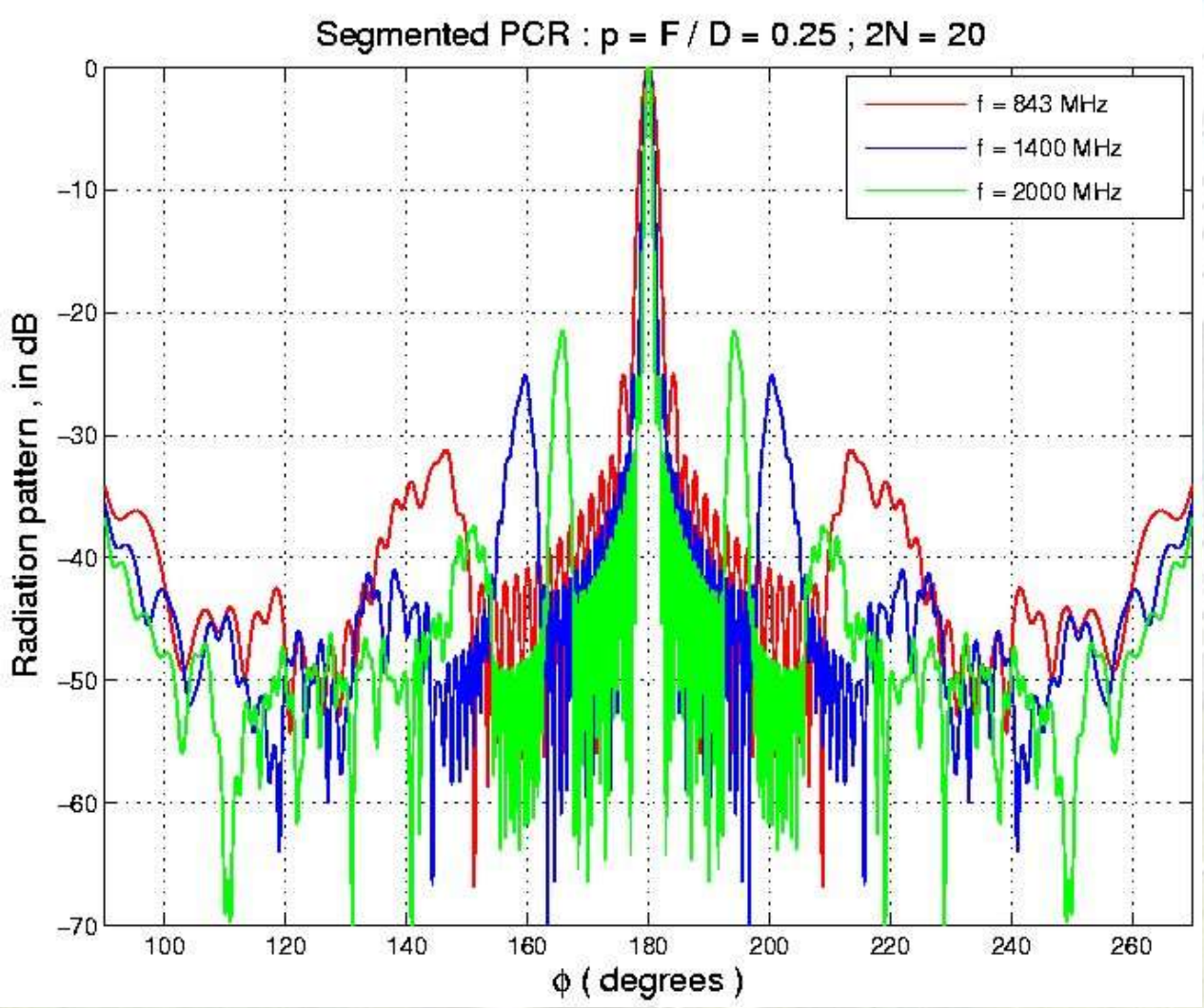
Molonglo segmented parabola design gives good performance to ~2 GHz

Piecewise linear fit to parabola shape



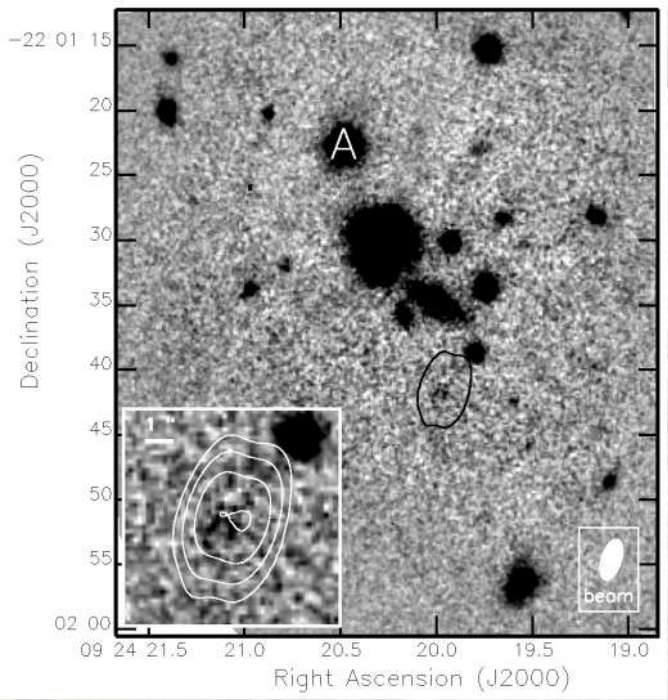
- Mesh supported at 0.6 m (2 ft) intervals in x direction.
- Each section gives the same error for a linear fit to a parabola.
- **0.1 dB loss at 1420 MHz.**
- **f/D = 0.25**

Simulations to test surface approximation



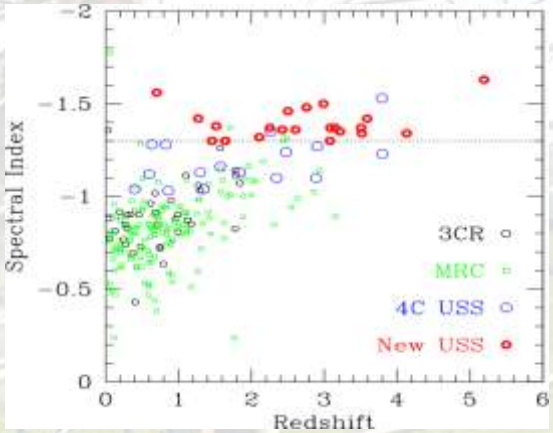
Science goals when wider spectral coverage: High-redshift radio galaxies

FX correlator: wide-band radio spectrometry

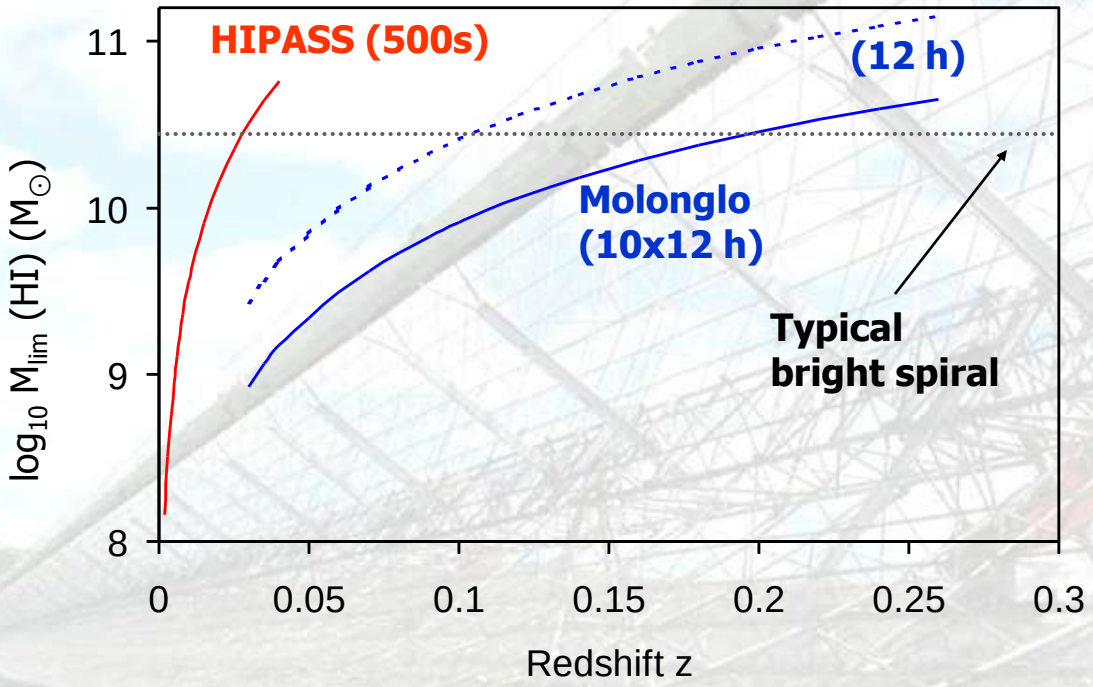


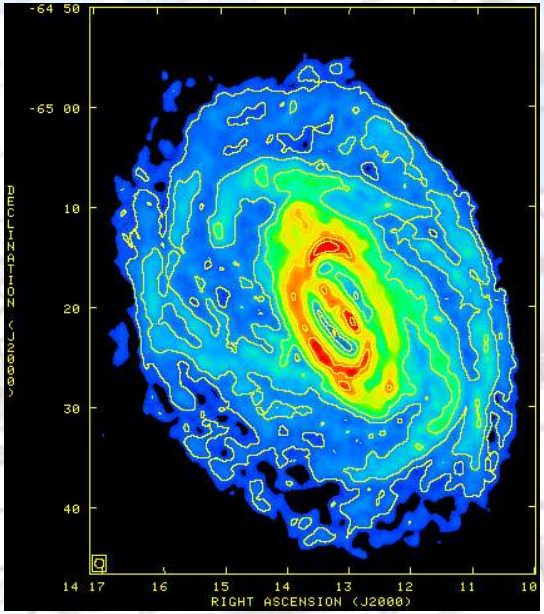
Radio galaxy TN0924-2201 at z=5.19
(van Breugel et al. 1999)

Radio spectral index measurements over the range 300 –1400 MHz are an efficient way of selecting high-redshift (z>3) radio galaxies (e.g. de Breuck et al. 2000, 2004).



High-redshift HI emission in galaxies





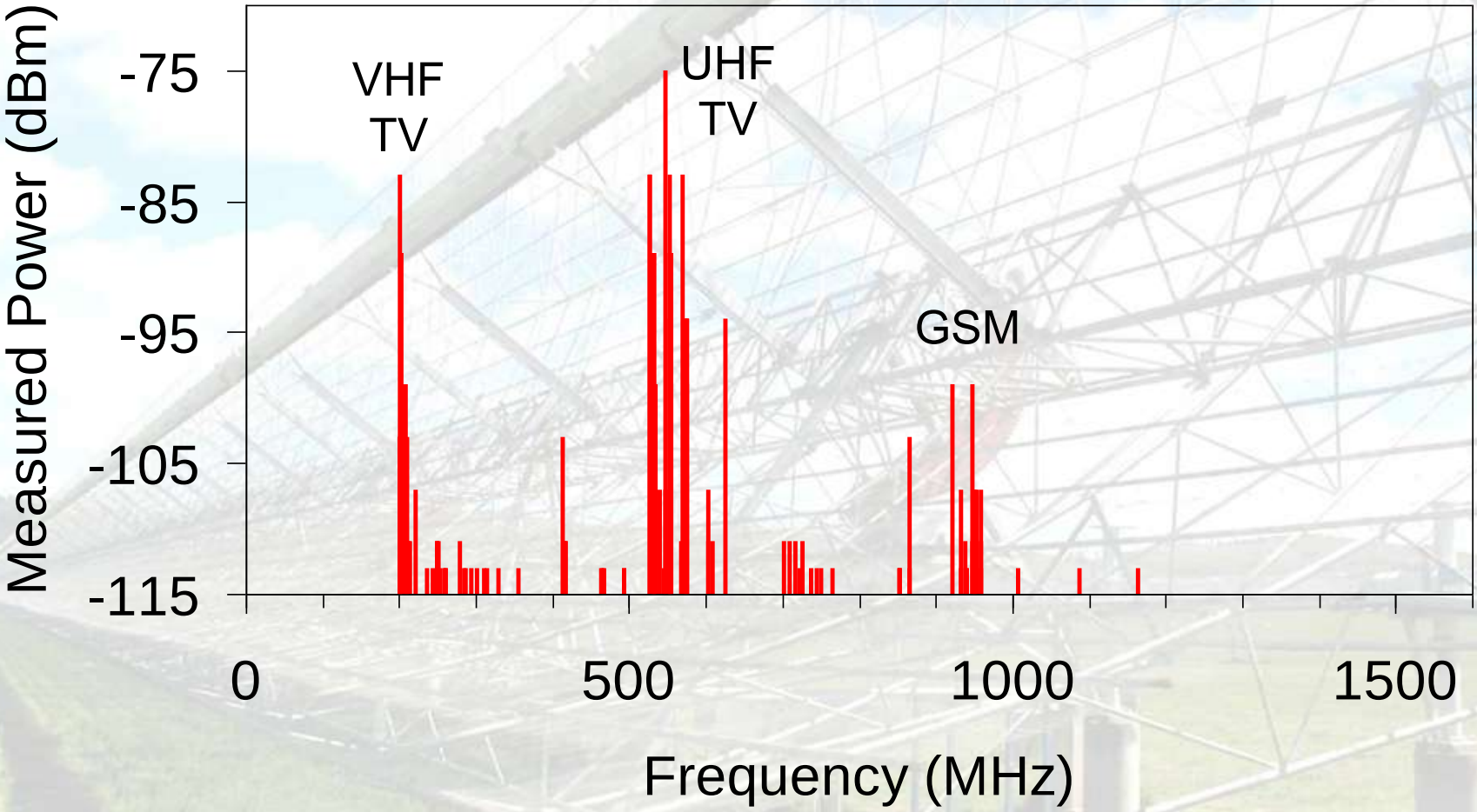
HI in the nearby Circinus galaxy (Jones et al. 1999)

The Molonglo telescope will reach HI mass limits typical of bright spiral galaxies at z=0.2 (lookback time ~3 Gyr), allowing a direct measurement of evolution in the HI mass function.

Low frequency unique science opportunities for SKAMP

- 500 – 900 MHz (z = 0.6 – 0.8) - HI absorption outside optical (DLA) range & continuum outside NTD range
- 900 – 1100 MHz (z = 0.3 – 0.6) - large collecting area benefits in absorption survey (overlaps NTD)
- 1100 – 1200 MHz (z = 0.17 – 0.3) - HI emission studies hard, needs large collecting area
- 1200 – 1400 MHz – possibly less optimal performance (NTD strength)

RFI at Molonglo 200-1500 MHz (Measured 25 June 2001)

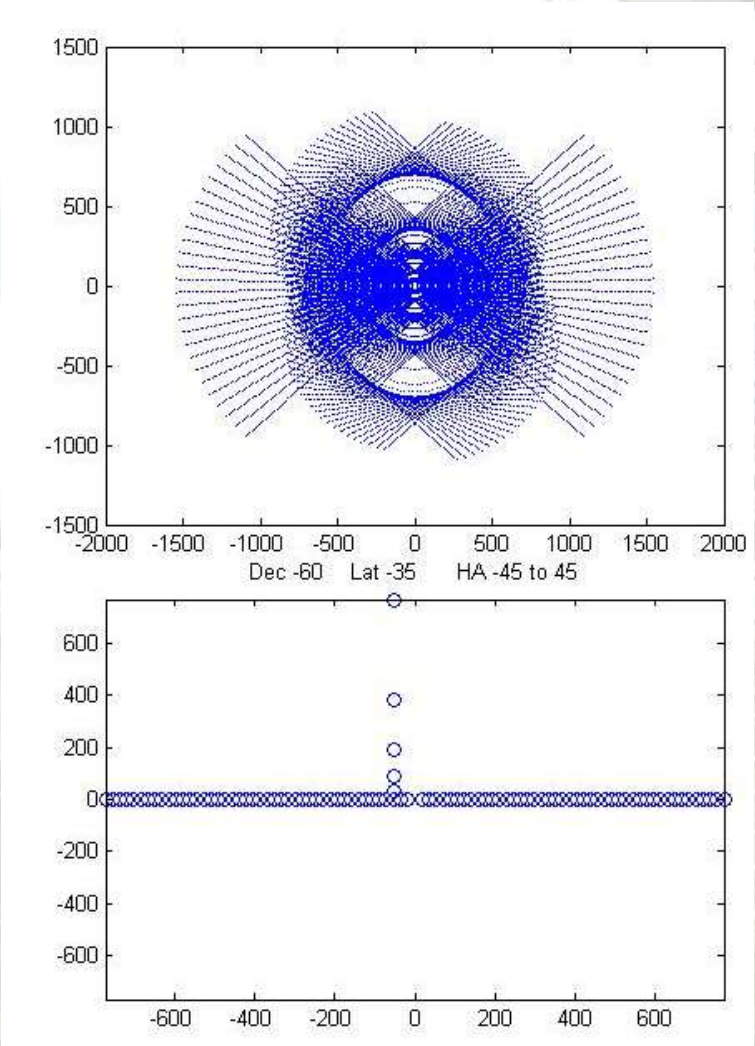


RFI measurements in the field at Dept of Defence HQ site

Campbell-Wilson, Briggs, Mitchell

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

A further extension: *uv*-coverage with additional stations on NS baselines??



- Good image fidelity in 6 hours
- Small reduction in sensitivity
- Model for 5 additional stations

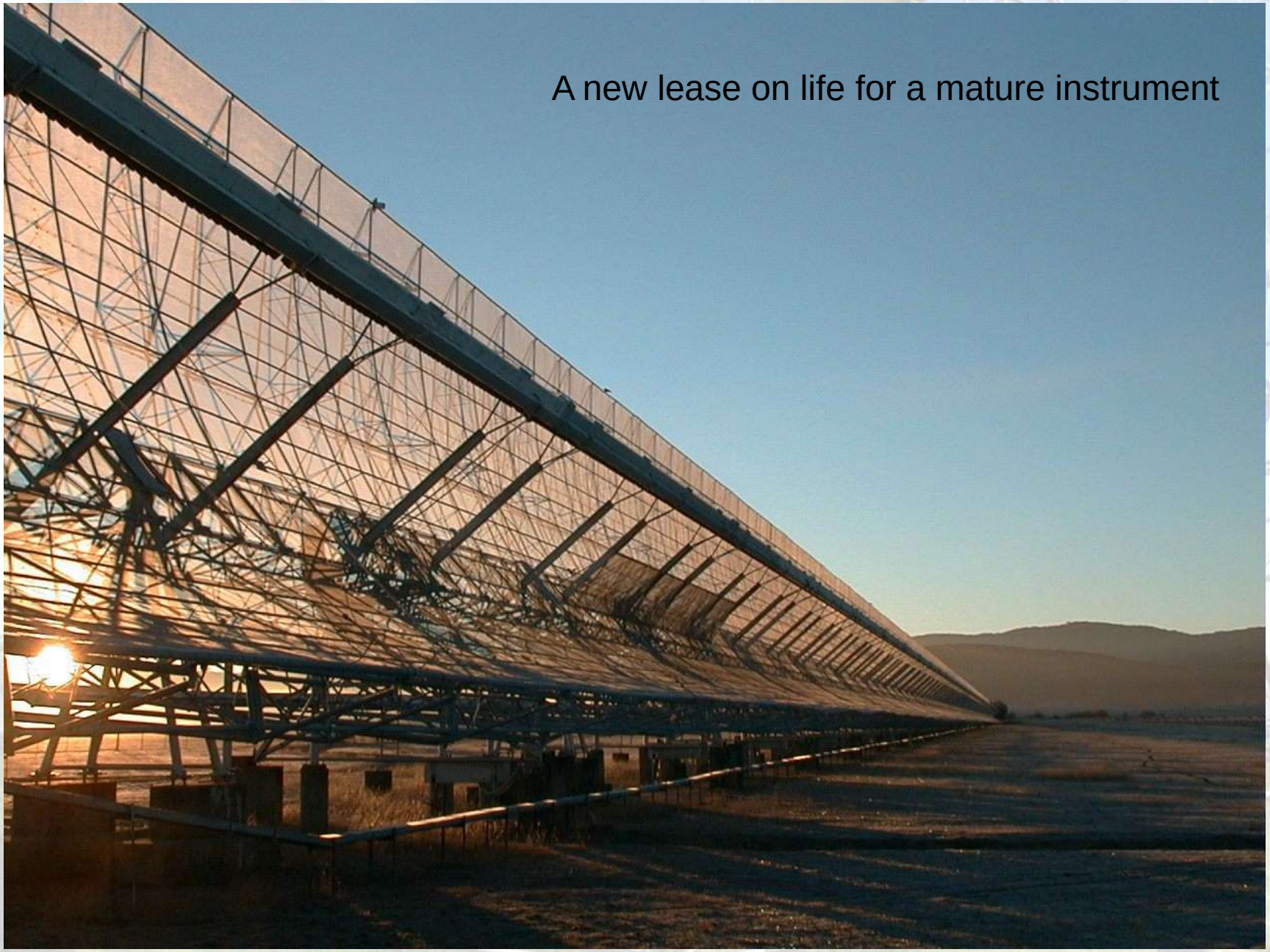
- (Bunton 2005)

Summary of key science goals

- Blind survey of HI absorption in high redshift galaxies – initially z~0.7, extend later. Test of mass-assembly of galaxies predictions from CDM scenario.
- HI in emission – measure mass function directly.
- Magnetic field tomography – measure diffuse Galactic polarisation and RMs from many extragalactic sightlines.
- High redshift galaxies found as USS sources.
- ISM structures – SNRs & RRLs

Summary of SKAMP Project status

- 96-station continuum correlator being commissioned & debugged. (SKAMP 1)
- Optic fibre network being laid, spectral-line correlator designed, PFBs & digital IF system in planning, calibration & image processing software being planned. (SKAMP 2)
- 8-element module of prototype feed designed & nearing completion, test station under construction, beam-formers being designed. (SKAMP 3)


A new lease on life for a mature instrument