SKA - The next steps...

An update on planning for the Square Kilometre Array:

- Jan 2002: 'Level 1 science drivers' (unique, high-priority science) for SKA identified by ISAC working groups
- July 2002: Release of seven engineering concept studies
- August 2002: Aim to identify critical issues related to science/engineering/budget trade-offs (input welcome). Where are more calculations/simulations needed?
- Aug/Sep 2002: ARC CoE proposal

The Square Kilometre Array (SKA)

The next generation radio telescope

Main goals:

- Large collecting area for high sensitivity (1 km^2), 100x sensitivity of current VLA.
- Array elements (stations) distributed over a wide area for high resolution (needed to avoid confusion at very faint flux levels).
- For good *uv* plane coverage (especially for HI observations), stations can't be too sparse.

Proposed Specifications for the SKA (SKA Technical Workshop, 1997)

Frequency range	150 MHz – 20 GHz
Imaging field of view	1 degree at 1.4 GHz
Instantaneous beams	100
Angular resolution	0.1 arcsec at 1.4 GHz
Spectral channels	10,000
Image dynamic range	10^6 at 1.4 GHz
Brightness sensitivity	1K at 1.4 GHz

SKA timeline

- 2000 ISSC formed (Europe; US; Australia, Canada, China, India)
- 2001 EMT, ISAC formed
- 2002 Concept studies, 7 designs
- 2005-6 Agreement on technical implementation and site
- 2008 SKA scientific and technical proposal completed
- 2010 SKA construction begins
- 2015 SKA completed

SKA Science Goals

- ***“The driving ambition for this new facility… is no less than to chart a complete history of time”*** (Taylor & Braun 1999)

- Structure and kinematics of the universe before galaxy formation
- Formation and evolution of galaxies
- Understanding key astrophysical processes in star formation and planetary formation
- Tests of general relativity, etc.

HI and the Cosmic Web

- Spectra of QSOs show many deep Ly-α absorption lines due to low col. density hydrogen (10^{16} –10^{17} cm^{-2})
- Where from?
  - diffuse galaxy halos ?
  - undetected low SB galaxies ?
  - dwarf galaxies ?
  - the “cosmic web” ?
- Predicted by CDM simulations → filaments and sheets with “galaxies” in the over-dense regions
- SKA will detect the web via HI in emission!
  All-sky survey → $<10^{17}$ cm^{-2}
  Deep field survey → $<10^{16}$ cm^{-2}

SKA

SKA sensitivities for HI

$\Delta V = 30\ \mathrm{km\ s^{-1}}$; $\Theta = 1''$
8 hour integration

Sensitivity: (each polarization)
$\sigma = 3.8\ \mu\mathrm{Jy/beam} = 2.39\ \mathrm{K}$

Mass Sensitivity: (5 σ)
$\sim 1 \times 10^6\ M_\odot$ @ 100 Mpc
$\sim 4 \times 10^8\ M_\odot$ @ $z = 1$ (resolution ~ 10 kpc)

Sub-dwarf galaxies

$\Delta V = 300\ \mathrm{km\ s^{-1}}$ $\Theta = 1''$
8 hour integration

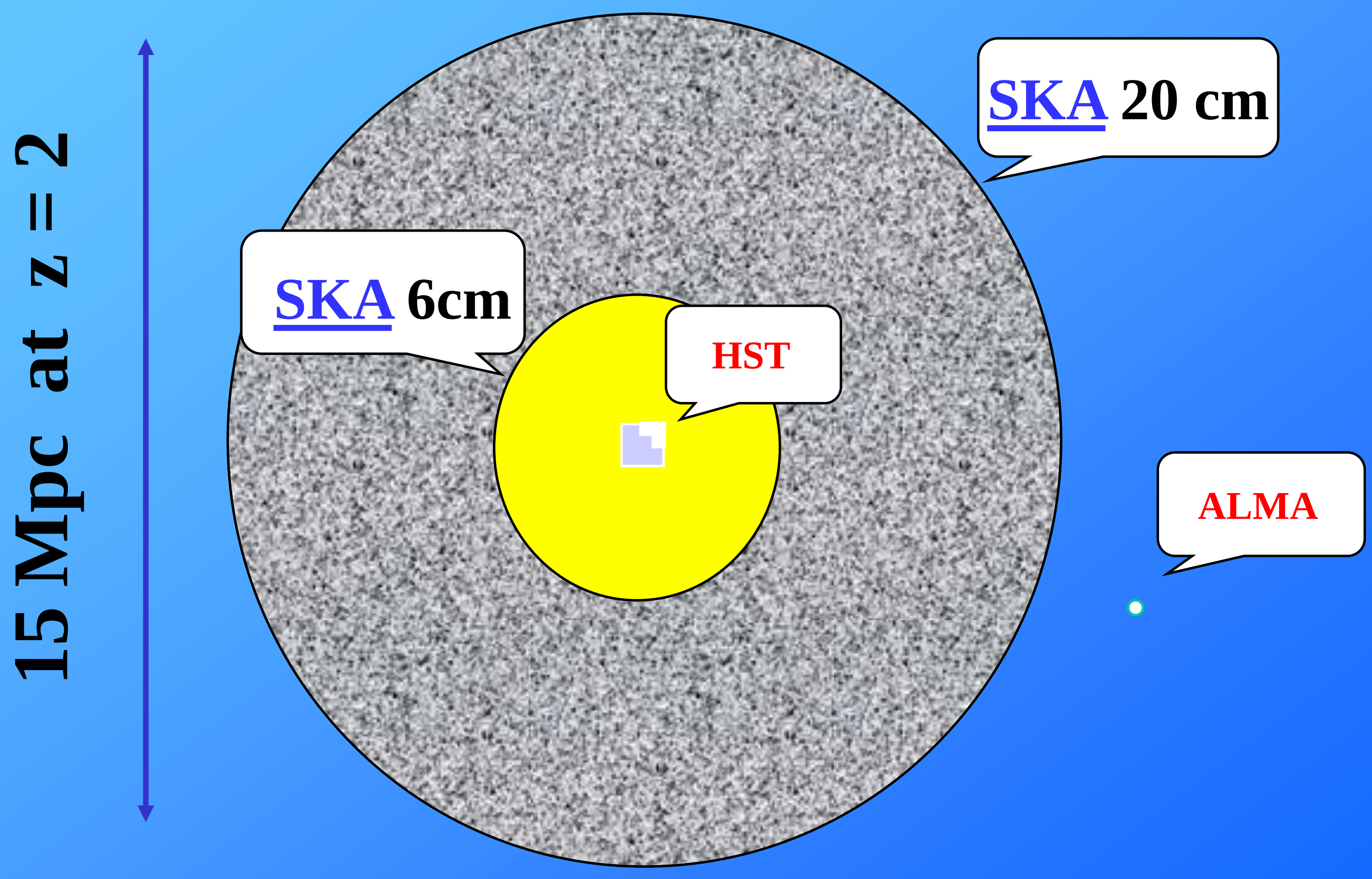
Sensitivity: (each polarization)
$\sigma = 1.2\ \mu\mathrm{Jy/beam} = 0.76\ \mathrm{K}$

HI Mass Sensitivity: (5 σ)
$\sim 3 \times 10^6\ M_\odot$ @ 100 Mpc
$\sim 1.2 \times 10^9\ M_\odot$ @ $z = 1$ (resolution ~ 10 kpc)
$\sim 3 \times 10^{10}\ M_\odot$ @ $z = 4$

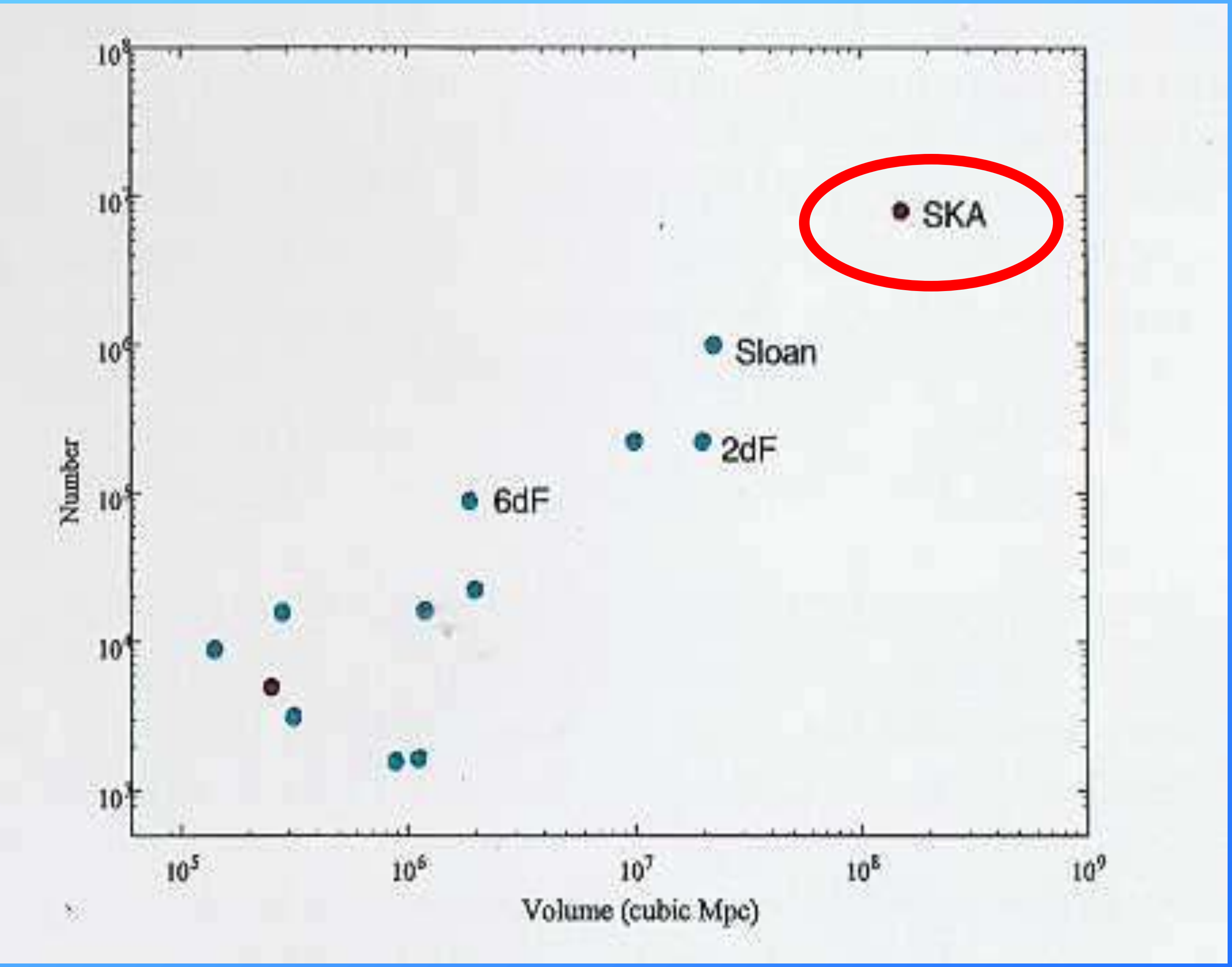
M101-like galaxies at z=4

SKA's 1^0 field-of-view

for surveys and transient events in 10^6 galaxies !



Large area survey of galaxies in HI

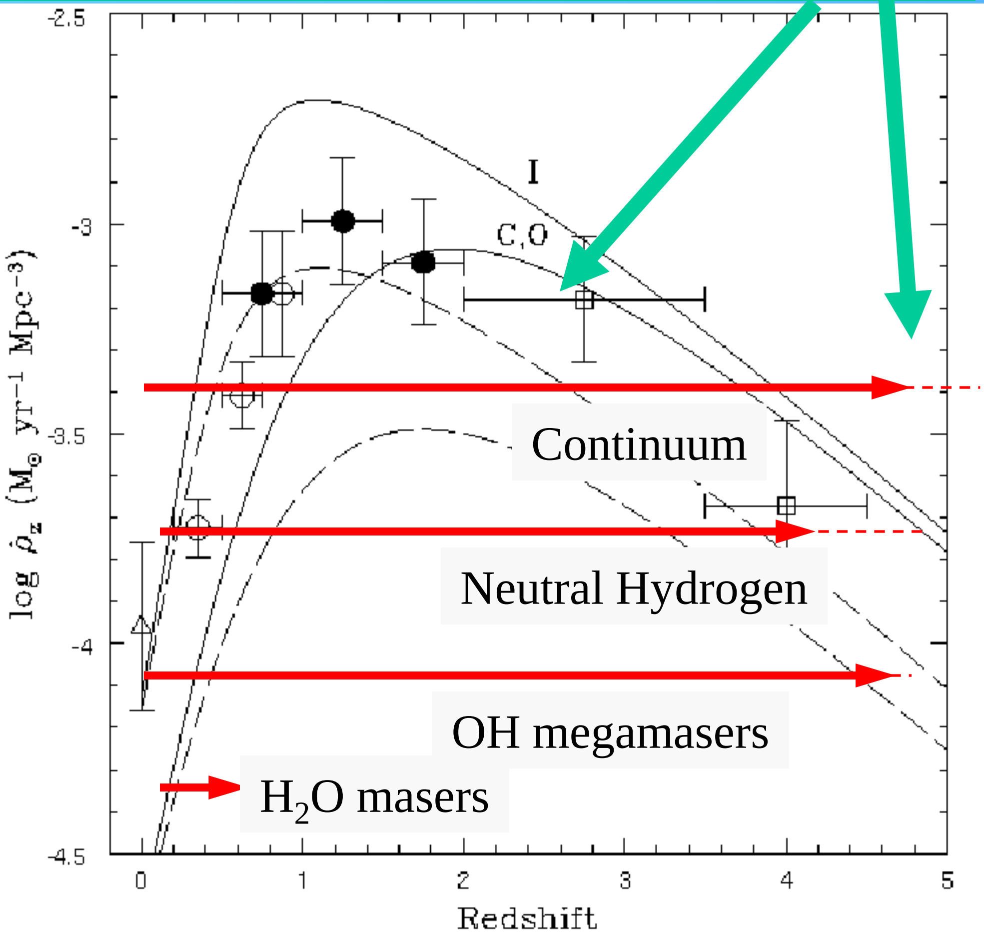


Redshifts and HI content of distant galaxies will be obtained for many galaxies

HI mass-based census of universe in the simplest atomic species…

Studying normal galaxies at high z

Unlike O/NIR radio is not affected by dust obscuration



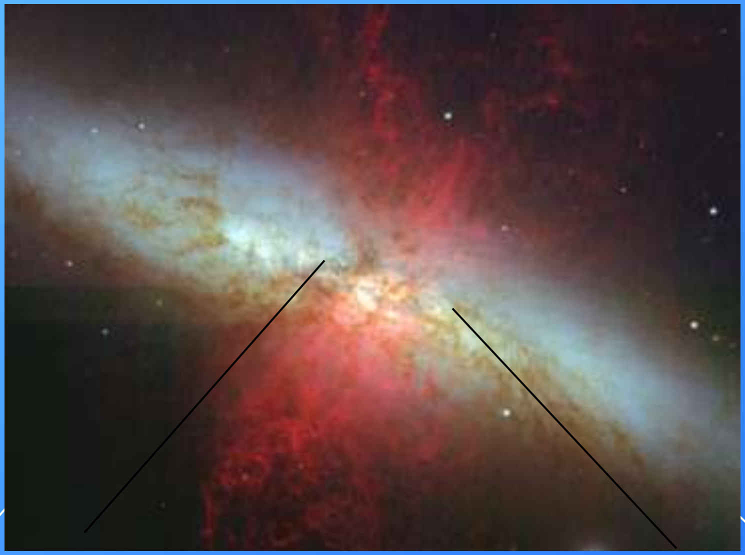
- In continuum, HI, OH and H_20 masers
- SKA sensitivity → radio image of any object seen in other wavebands
- Natural resolution advantage cf. ALMA, NGST, HST

SKA can study the earliest galaxies in detail

Star formation rates in the Universe

- Starburst galaxies e.g. M82
  - Radio VLBI reveals expanding supernovae through dust
  - Infer star birth rate from death rate rather directly
  - SKA: Image "M82s" to ~100Mpc
    : Detect "M82s" at high z
  - Calibrate integrated radio continuum → SFR at high z

Madau curve underestimates SFR at z>1.5



M82 VLA+ MERLIN+VLBI

Basic design criteria:

Sensitivity alone is not enough:
hence SKA

- Must be sensitive to a wide range of surface brightness

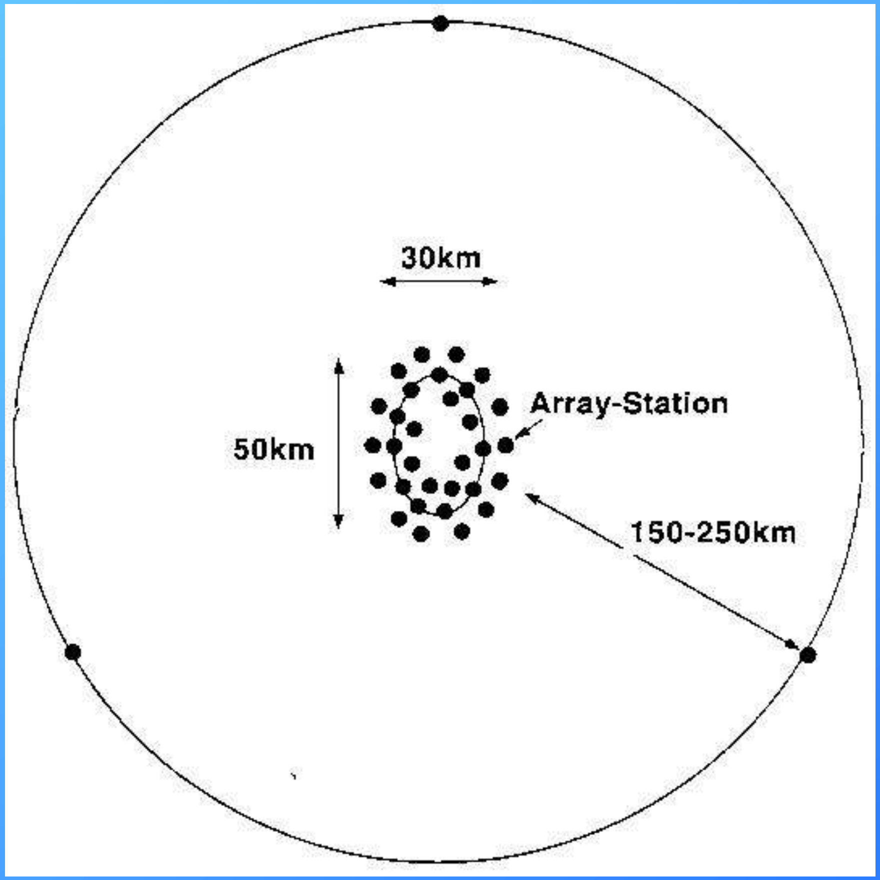
  → many “stations” in the array and wide range of baselines

- Must cover factor >10 frequency range

- Must have wide field & ideally multiple beams

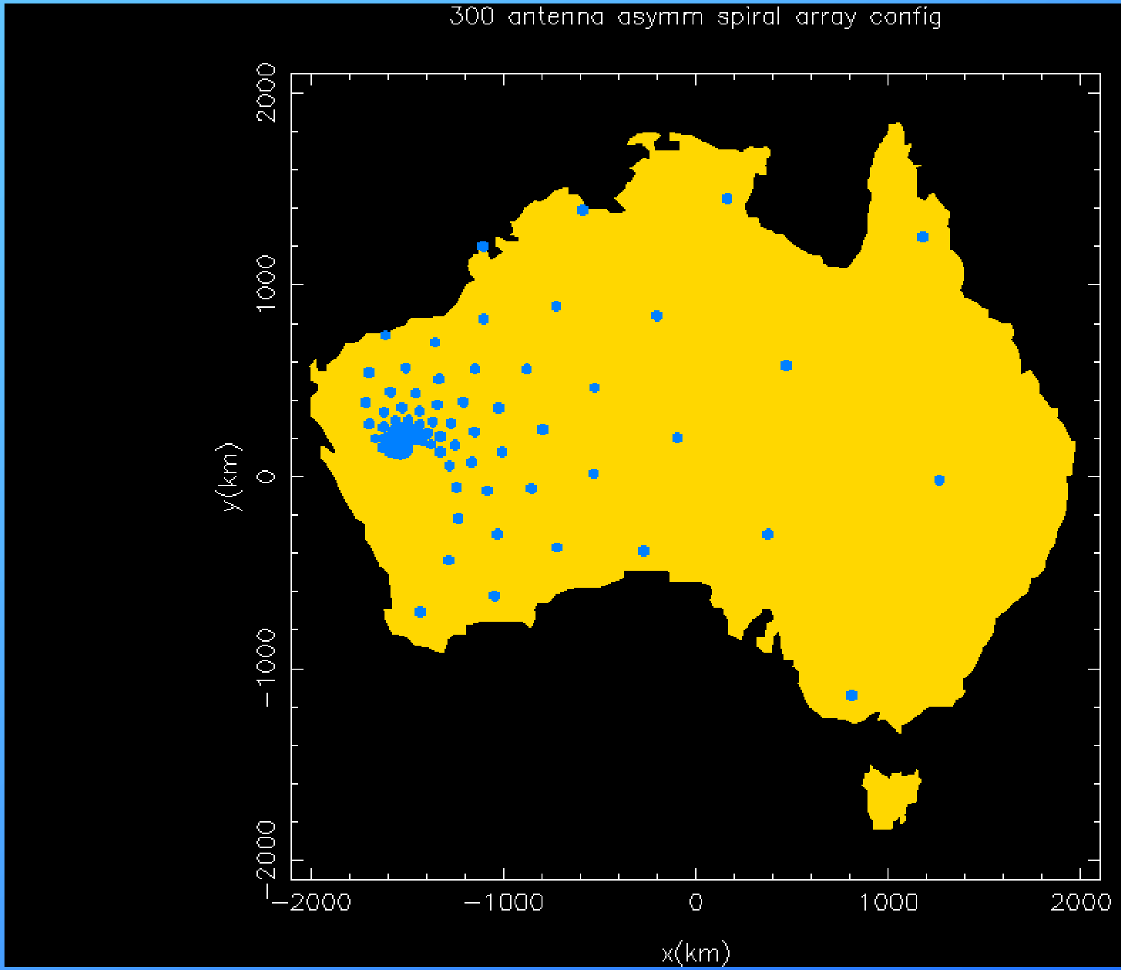
  → multi-user; surveying speed and interference mitigation

SKA Configurations



Determining (and agreeing on) the optimum SKA configuration is a significant challenge

For high resolution, array stations are distributed across a continent

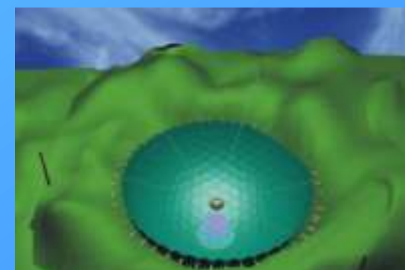


(M. Wieringa)

SKA design concepts

July 2002

US ATA



China KARST

Australia Luneburg Lenses

Canada Large reflector

Dutch phased array

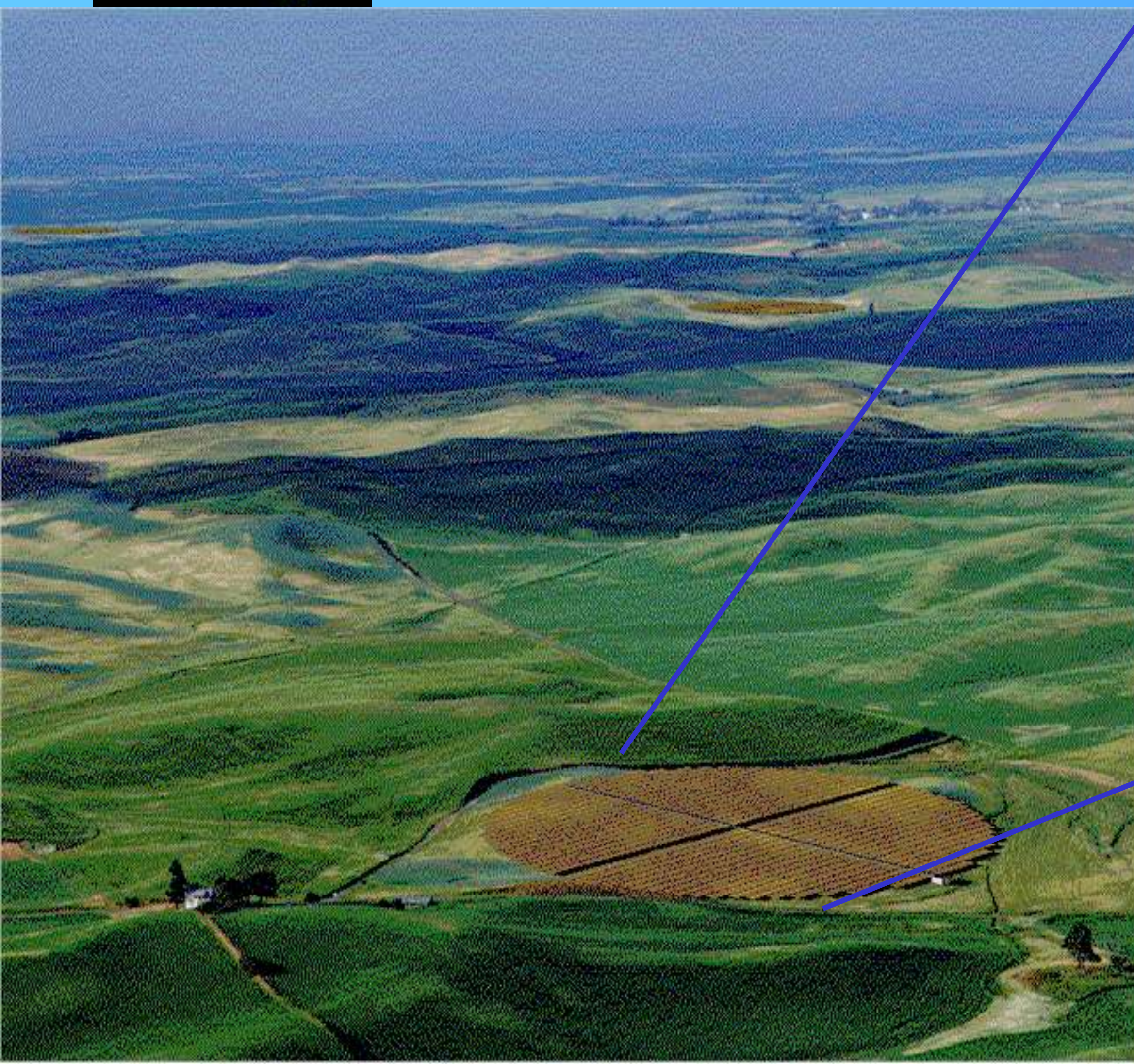
Australia cylindrical paraboloid

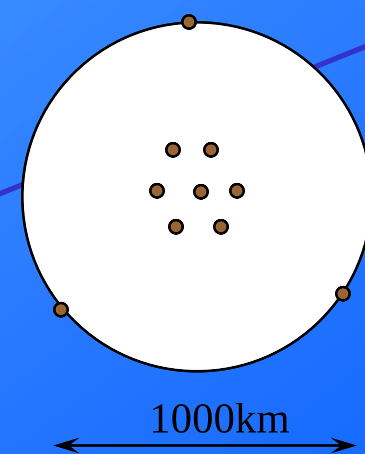
+India: GMRT-model dishes

‘Large N, Small D’ Array
(USA)

Advantages:
Reaches
high-freq.
(34 GHz)

Phased arrays (Europe)

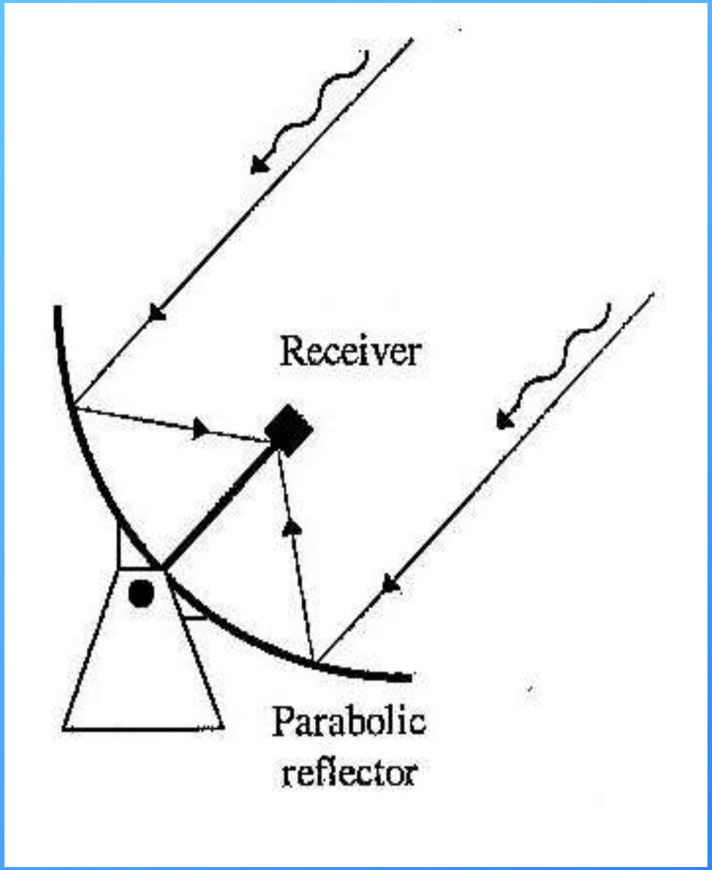


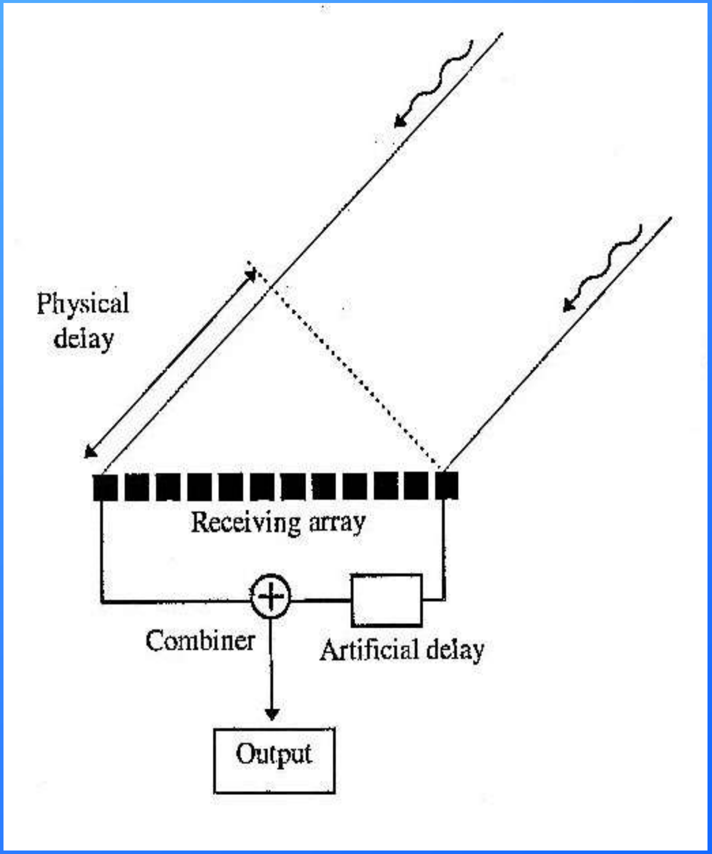


(Courtesy NFRA)

Phased array concept

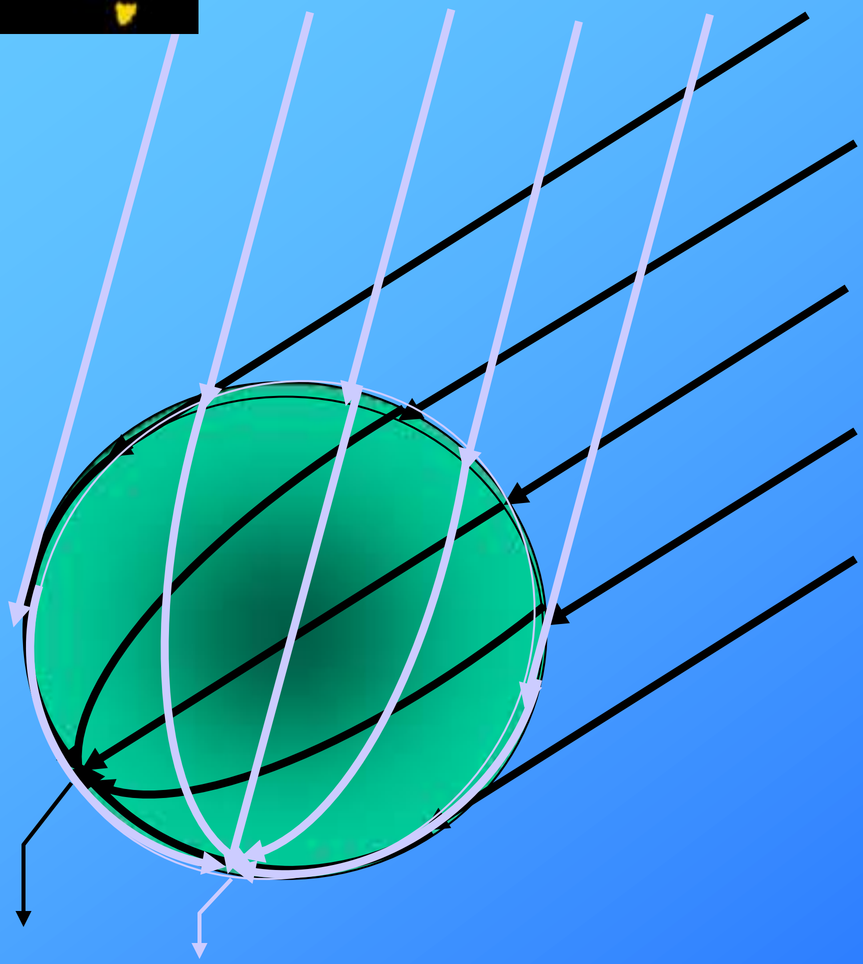
Replace mechanical pointing, beam forming by electronic means





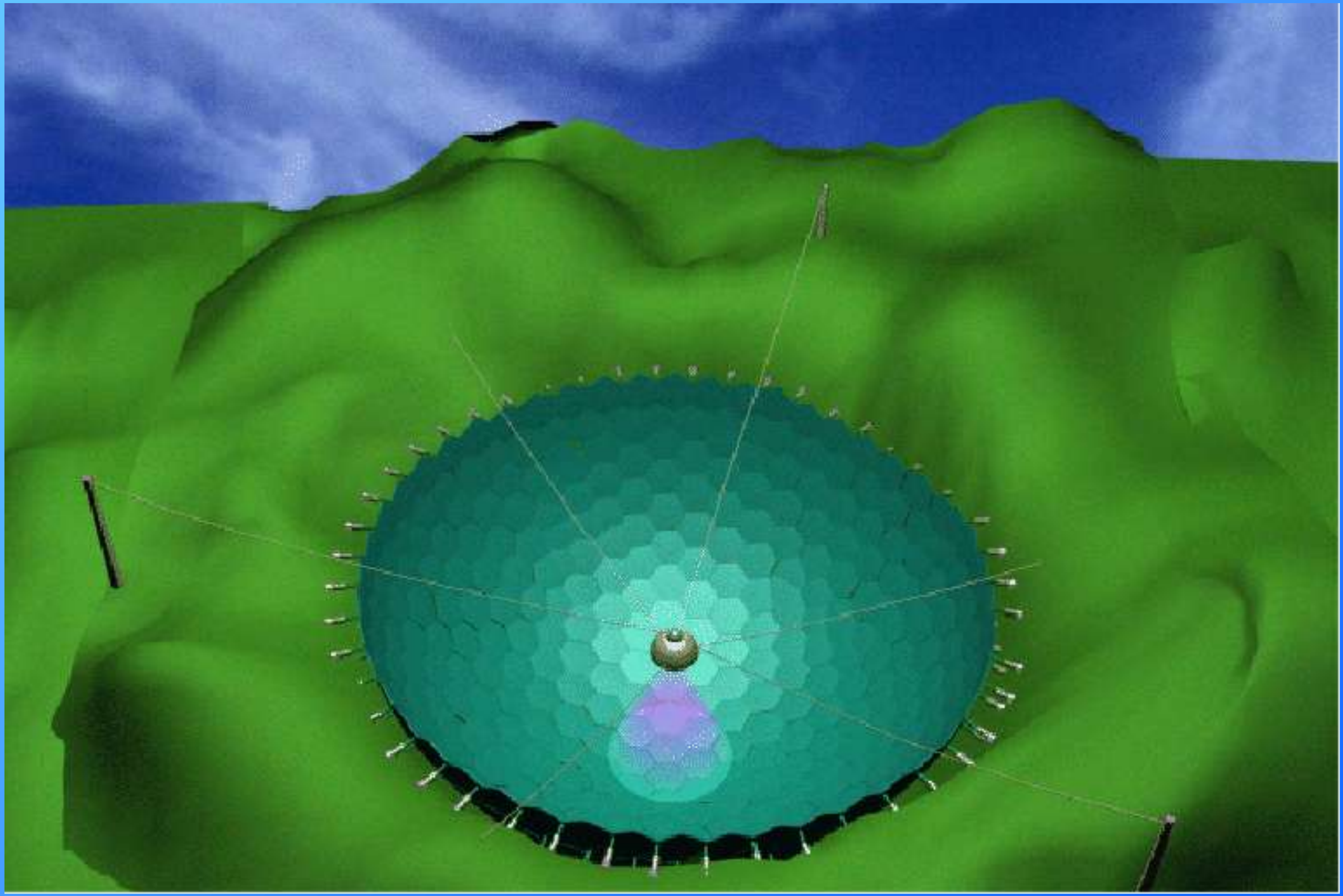
Array station of Luneberg lenses (Australia)

Luneburg Lens

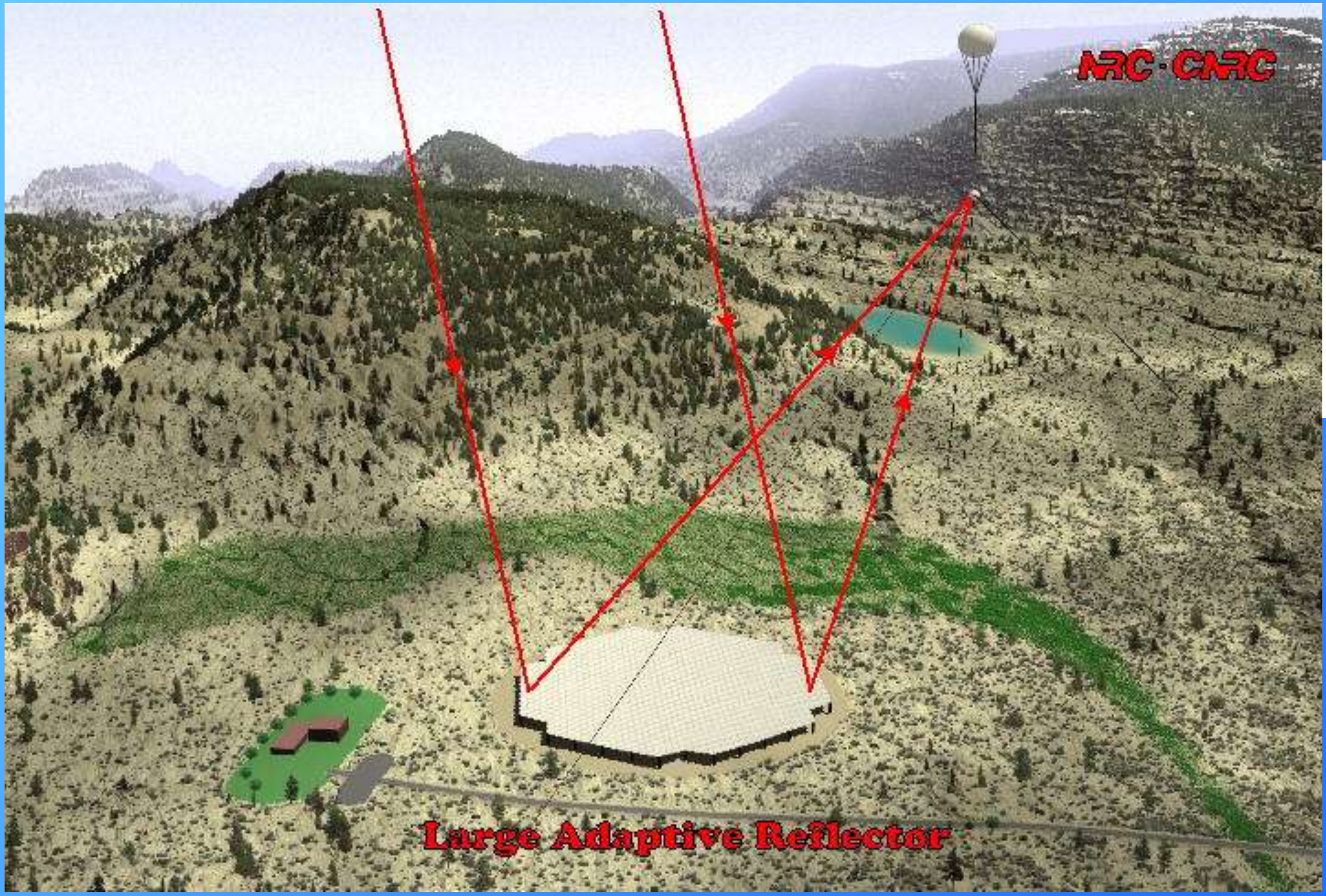


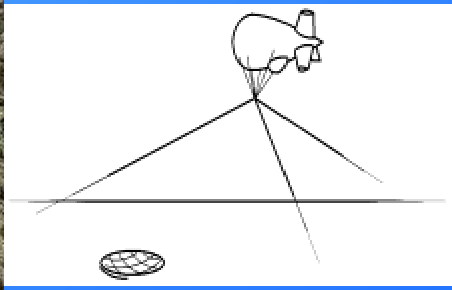
- Spherical lens with variable permittivity
- A collimated beam is focussed onto the other side of the sphere
- Beam can come from any direction

Large [Arecibo-like] Reflectors (China)

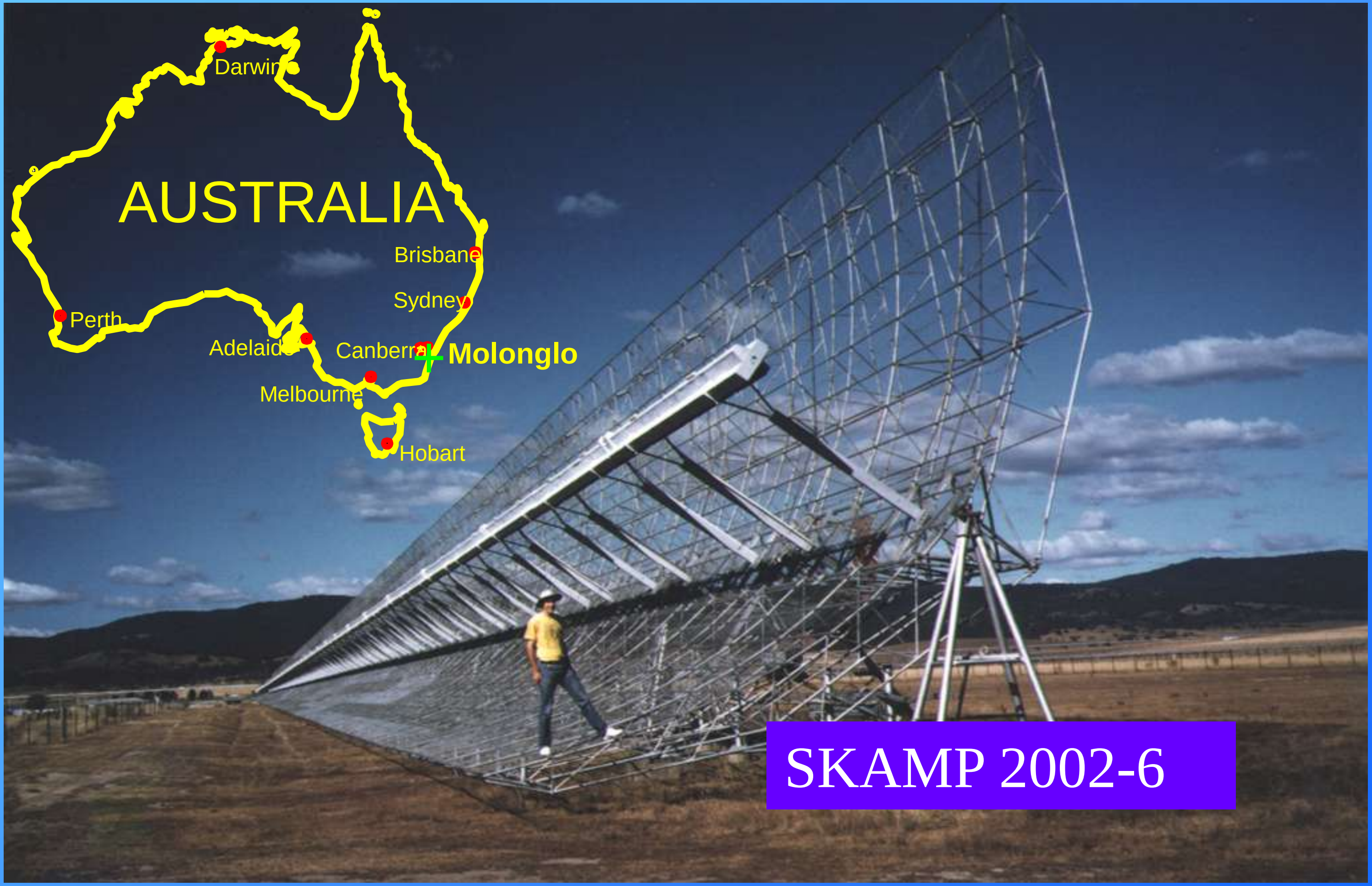


Aerostat-mounted receiver above Large Adaptive Reflector (Canada)





Cylindrical reflector (Australia)



ISAC Working Groups

1. *Nearby galaxies* (Chair: John Dickey, USA)
2. *Transient phenomena* (Joe Lazio, USA)
3. *Early Universe, Lge-scale structure* (Frank Briggs, Aust)
4. *Galaxy formation* (Thijs van de Hulst, NL)
5. *AGN and black holes* (Heino Falcke, Ger)
6. *Life Cycle of stars* (Sean Dougherty, Can)
7. *Solar system and planetary science*
8. *Intergalactic medium* (Luigina Ferretti, Italy)
9. *Spacecraft tracking* (Dayton Jones, USA)

Current Australian ISAC members: Frank Briggs (ANU), Carole Jackson (ANU), Geraint Lewis (AAO), Elaine Sadler (Sydney)

'Level 1 Science Drivers'

Jan 2002: Each ISAC working group identified the one or two most important science goals which are unique to SKA (level 1). Level 2 drivers are second priority or not unique to SKA.

e.g. WG4 (Galaxy formation) - "*Sensitive, wide-field HI 21cm and radio continuum surveys*"
(CO surveys, currently level 2, may be added)

Next goal for the ISAC is to study the seven concept proposals, determine to what extent they meet the requirements of the Level 1 Science Drivers, and provide feedback to proposers and EMT.

Some topics for discussion in Groningen (Aug 2002)

Low and high frequency limits: *Only US design goes above 9 GHz. Are frequencies above 5 GHz scientifically compelling?*

Multibeaming: *Are fast response times (~ 1 sec) likely to be needed? Is 10 sec, or 100 sec just as useful?*

Sensitivity: *Does the SKA need a 10^6 m^2 equivalent collecting area at all frequencies, or only below 1.4 GHz?*

Field of View: *What kind of trade-offs between field of view and bandwidth are acceptable (e.g. for HI surveys)?*

Input from everyone is welcome...