

# 21 cm Deep All Sky Survey: A Dark Energy Experiment

Jeff Peterson, CMU and Ue-Li Pen, CITA

- Baryon Oscillations
- 21 cm data
- Intensity Mapping
- Cylinder Telescopes
- Prototype



Prototype at LTV Steel, P'gh PA

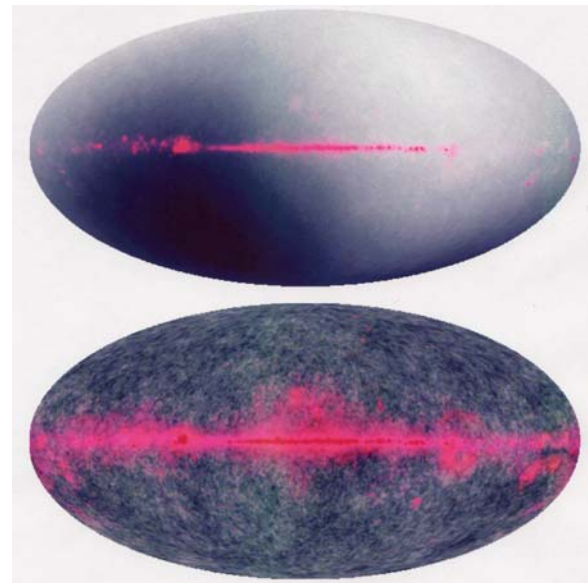
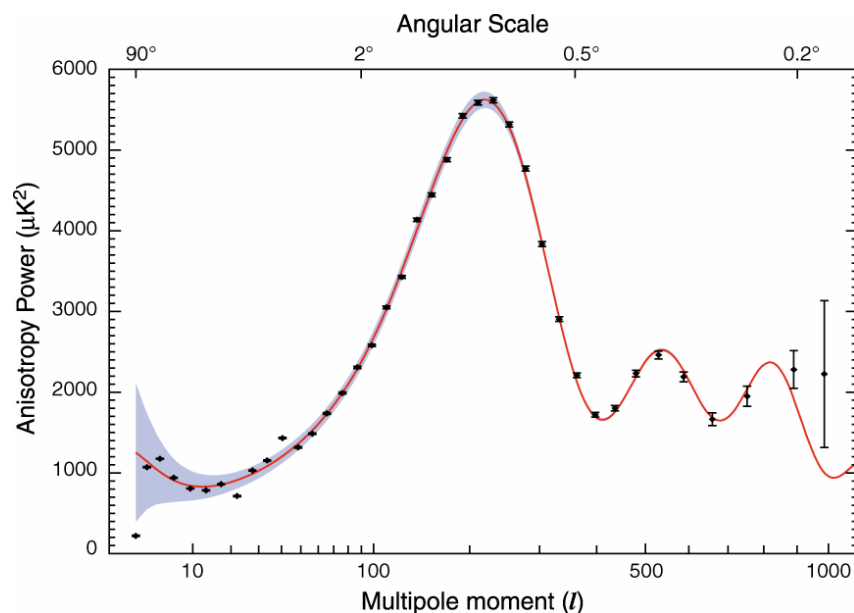
# The Cylinder Survey Study Group

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- Kevin Bandura,
- Bruce Taylor,
- Derrick McKee
- Jim McGee
- Steve Schweizer
- Uros Seljak (U. C Berkeley)
- Peter Timbie (U. Wisc.)
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- Christohpe Magneville
- Jim Rich
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- Marc Moniez
- 2 FTE engineer
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- Jason Salkinder (UCT)
- Jon Bunton (CSIRO)

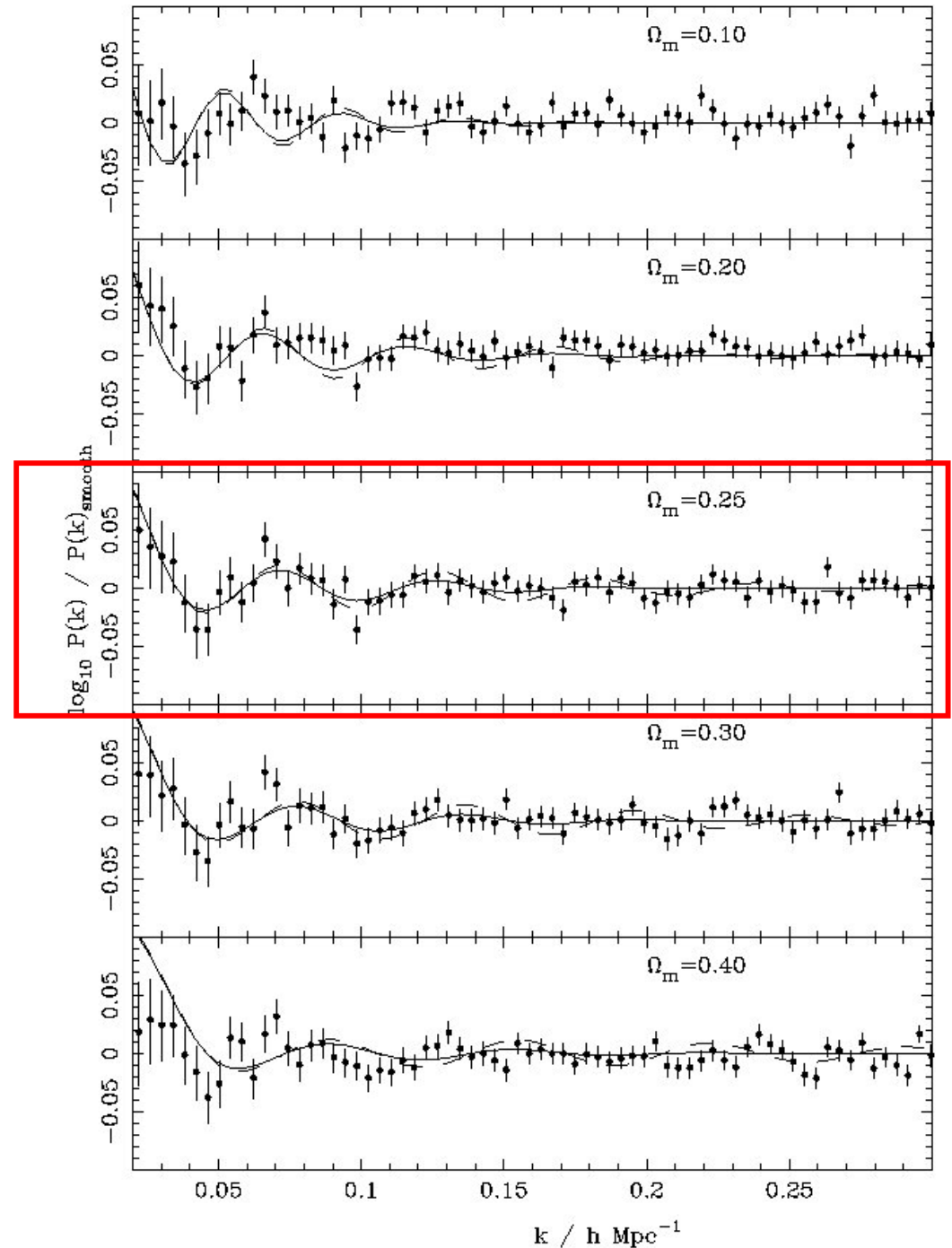
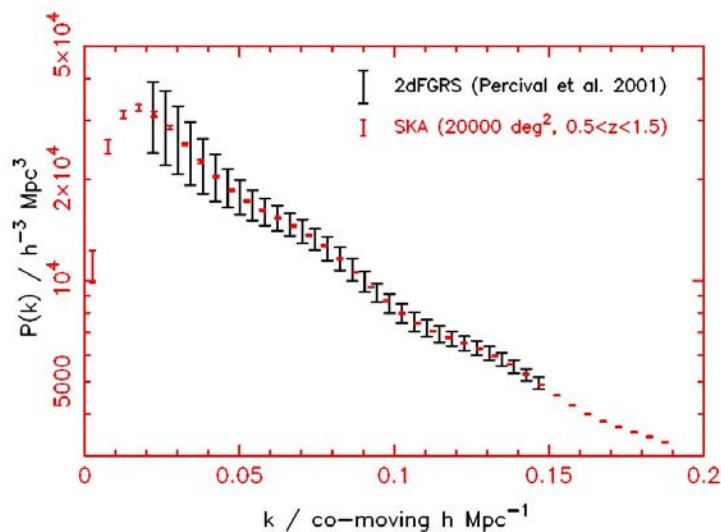


# The Universe is Accelerating

- But it must have been decelerating in the past.
- Acoustic oscillations give us the “standard ruler” to follow this transition.

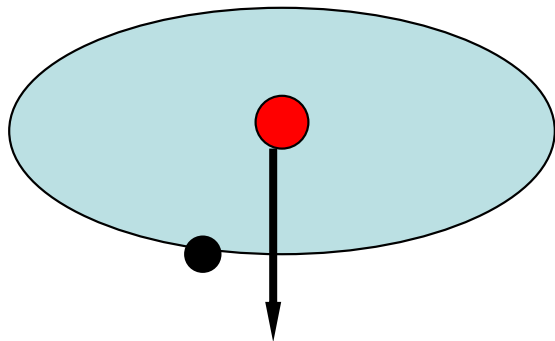
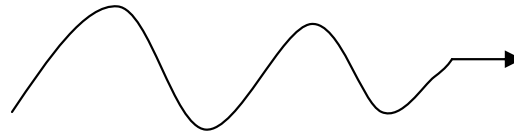
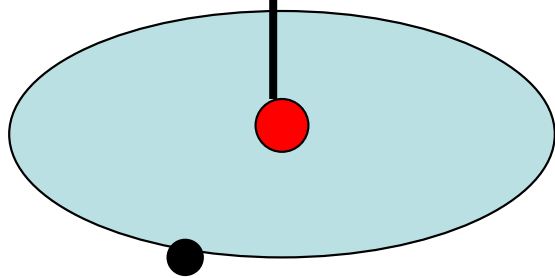


# Baryon Wiggles 'Detected' by SDSS and 2df



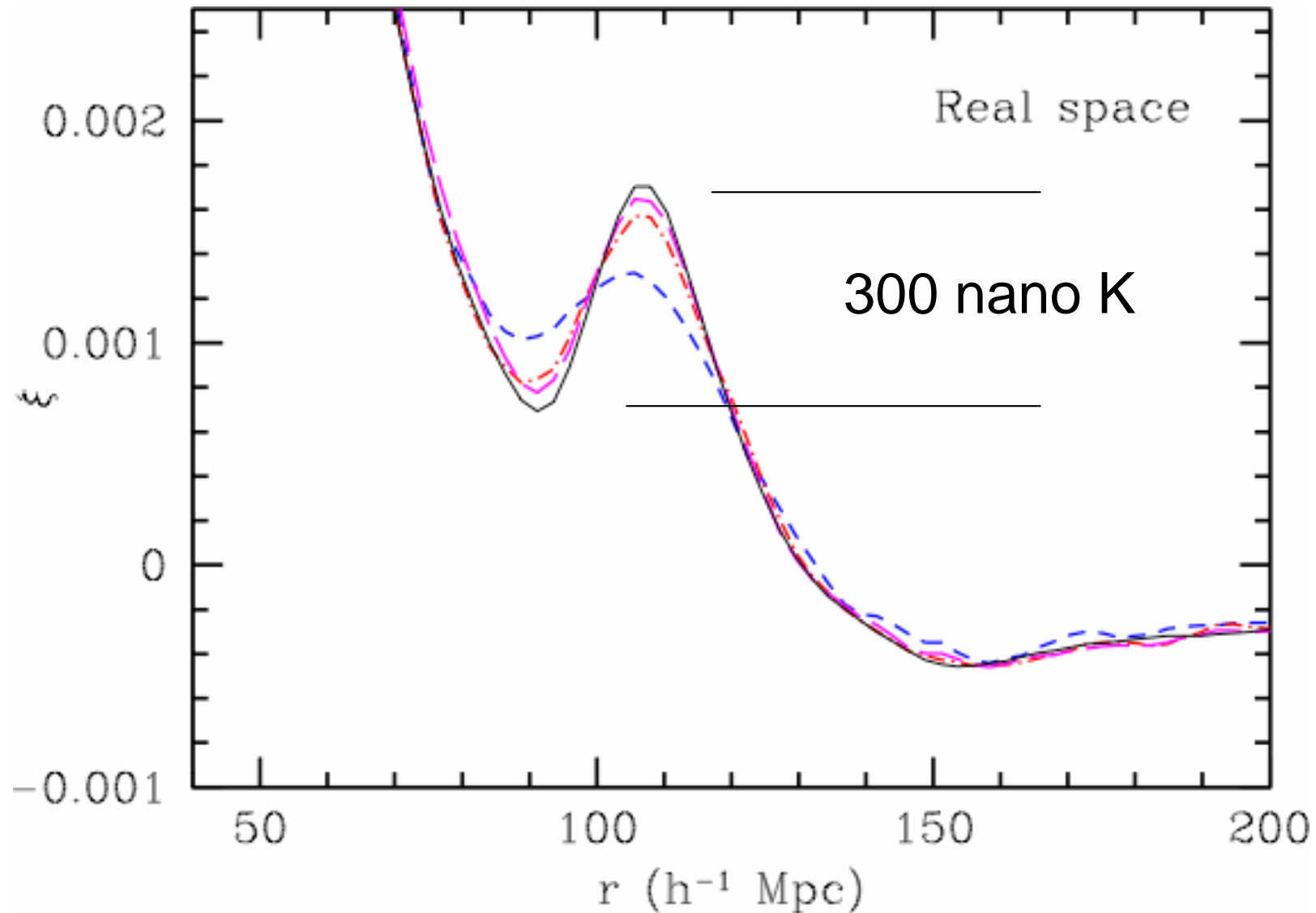
# Nuclear Hyperfine Transition of Hydrogen

- Cross section small—but hydrogen is abundant



1420 MHz

# The BAO peak in autocorrelation



# Should we detect individual galaxies?

Use a galaxy redshift survey?

Or

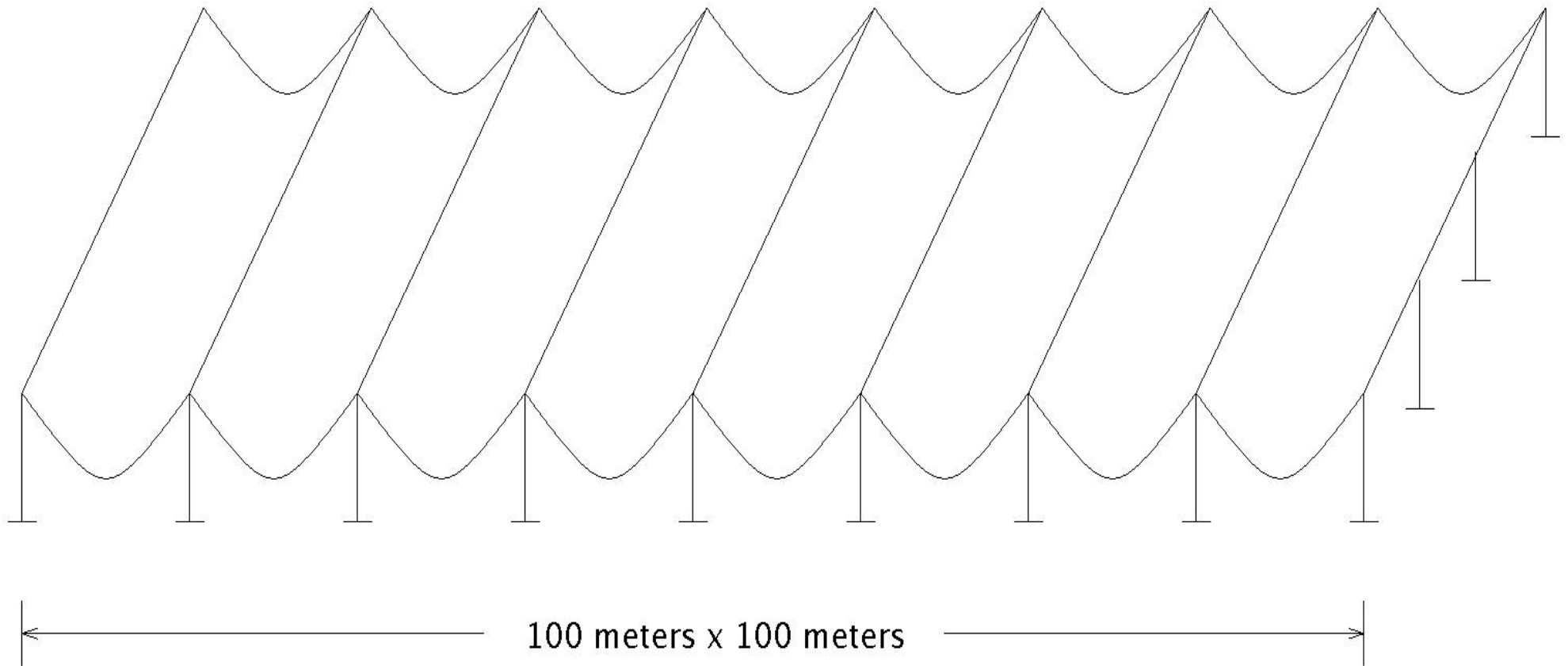
Use the 3-d intensity field directly?

A galaxy redshift survey  
requires  $.4 \times 10^6$  sq meter  
collecting area (HSHS)

- What if we just collect all emission in  
~20Mpc cells and map that (3DIM)?
- This requires only 10,000 sq meters

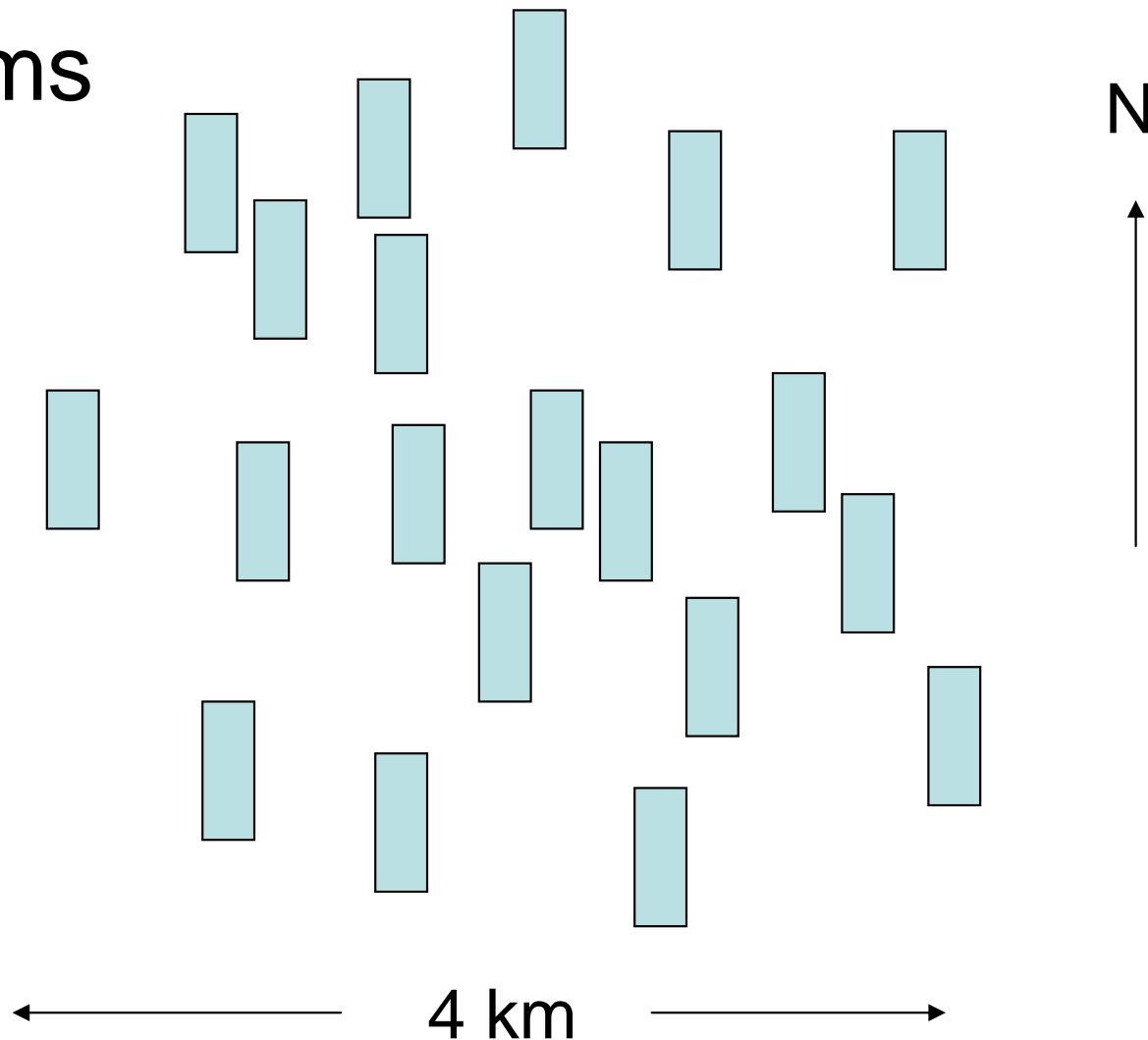


# A Possible 3DIM Layout



# Hubble Sphere Hydrogen Survey: 20-60 Cylinders each 400m long

- Line feeds at foci used to create 1024 beams

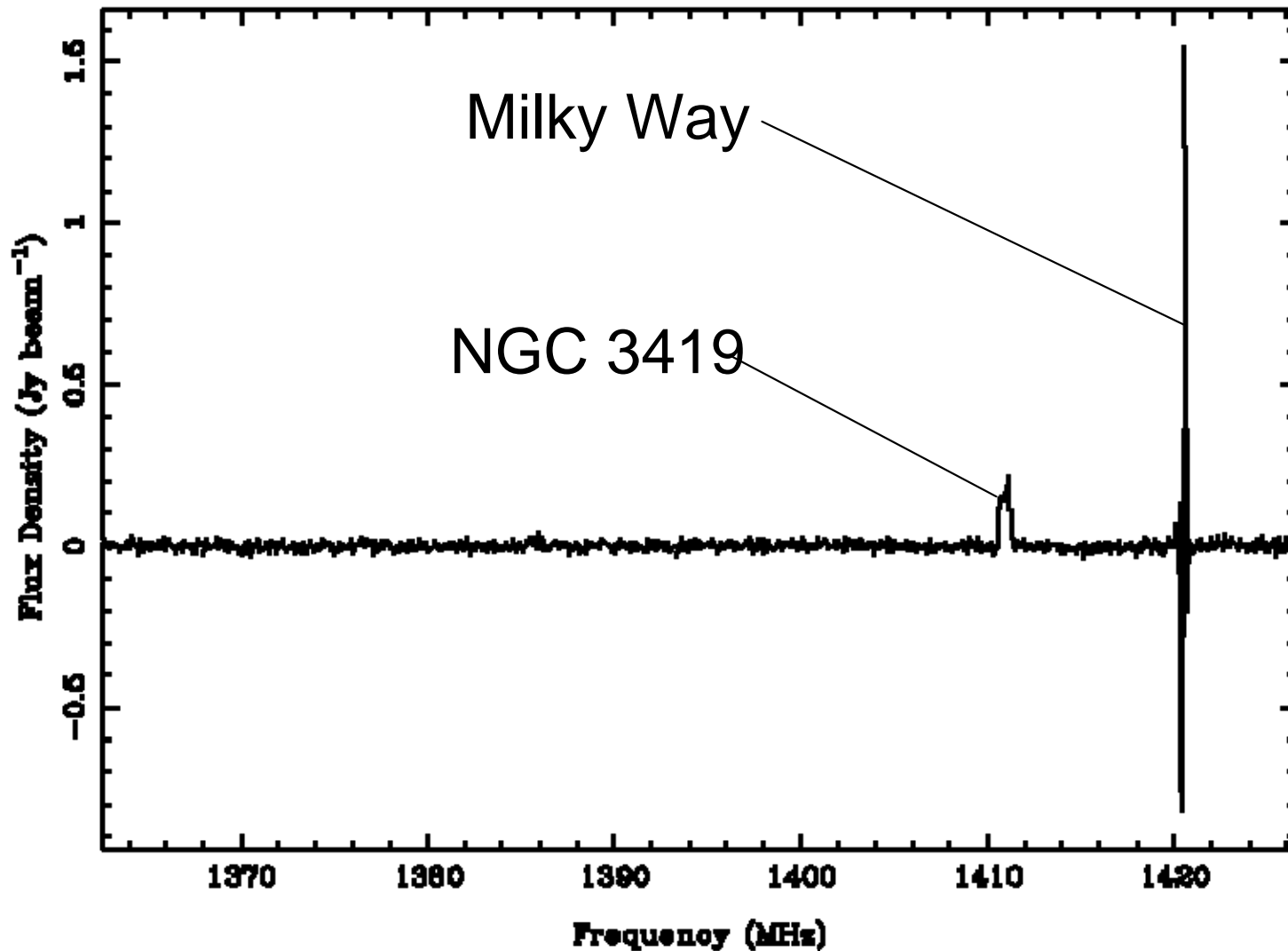


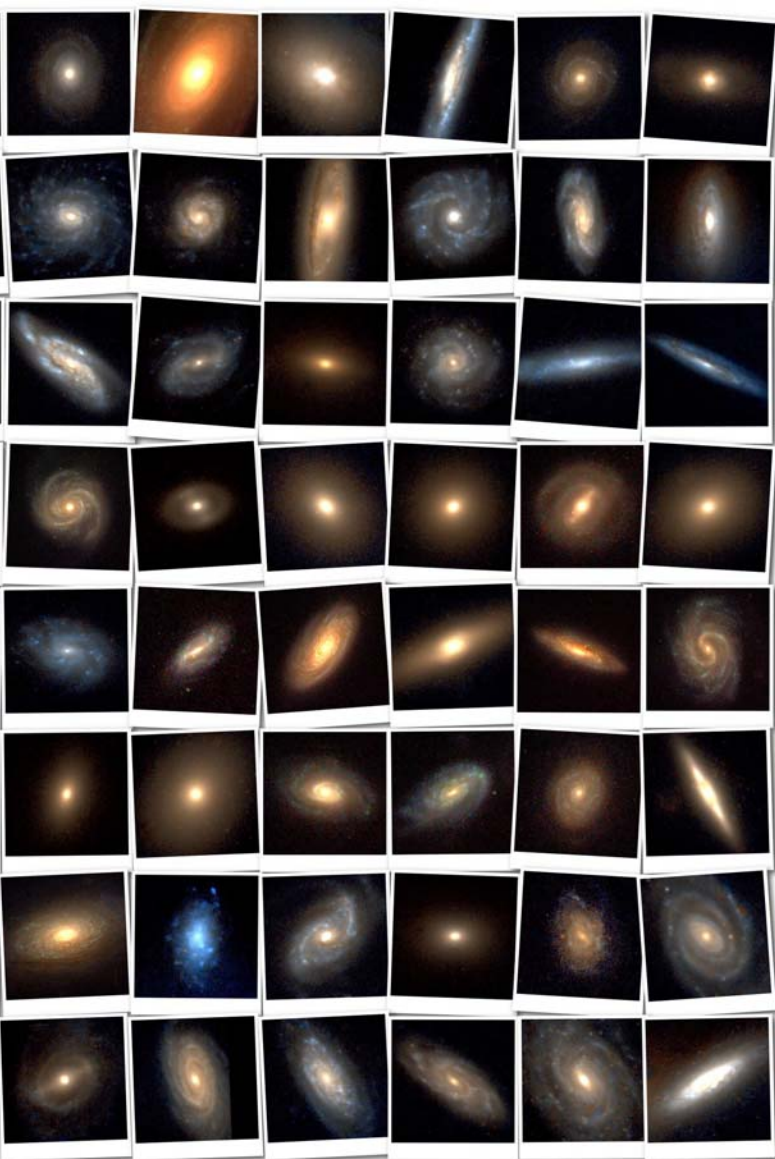
# Data from Parkes Telescope



Object: H004  
Requested: 10:04:00.00 -80:29:08.00  
Actual : 10:03:37.98 -80:23:18.98  
Equinox : J2000

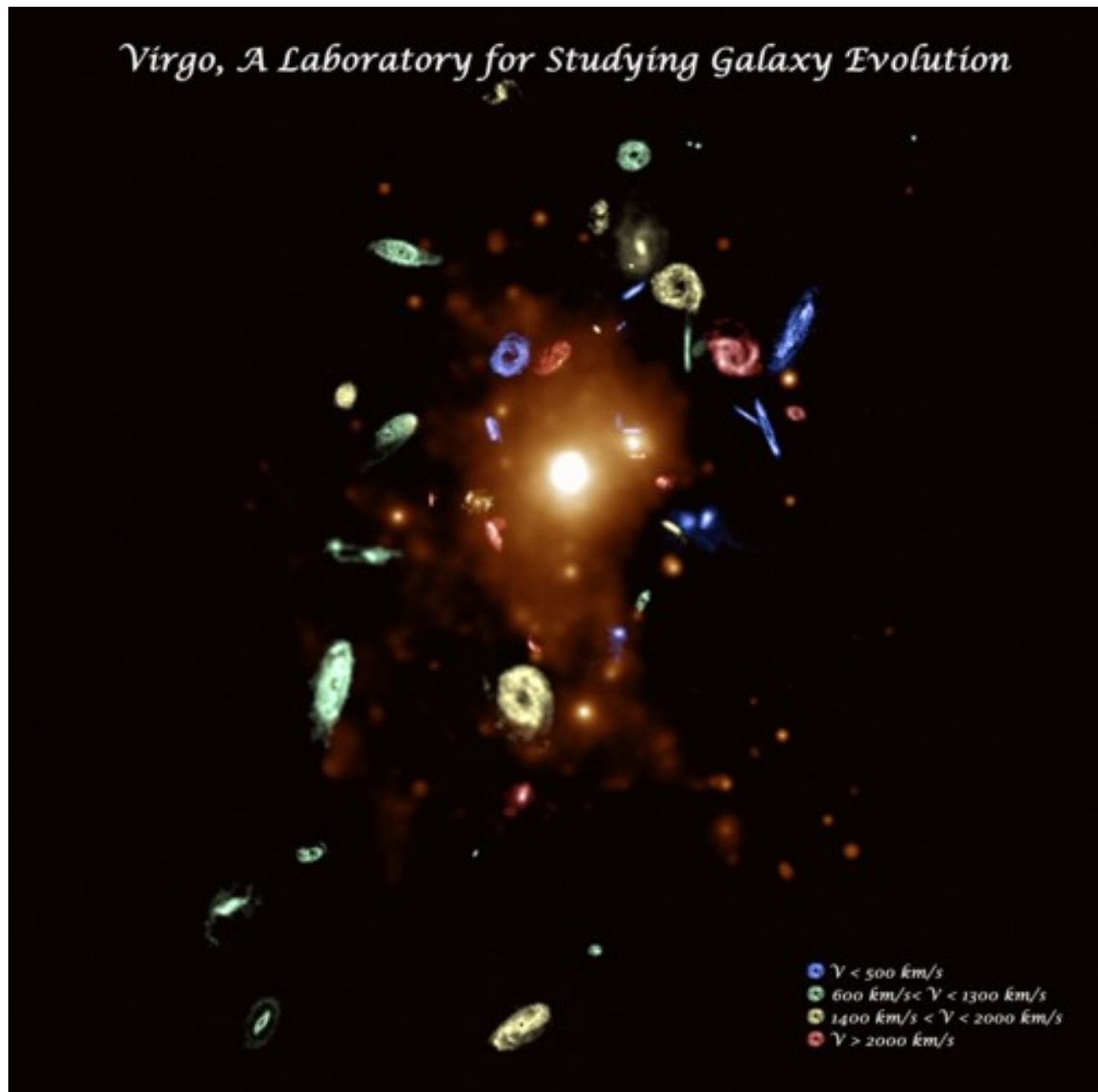
HIPASS public data release - v1.2 May 13 2000 (south)





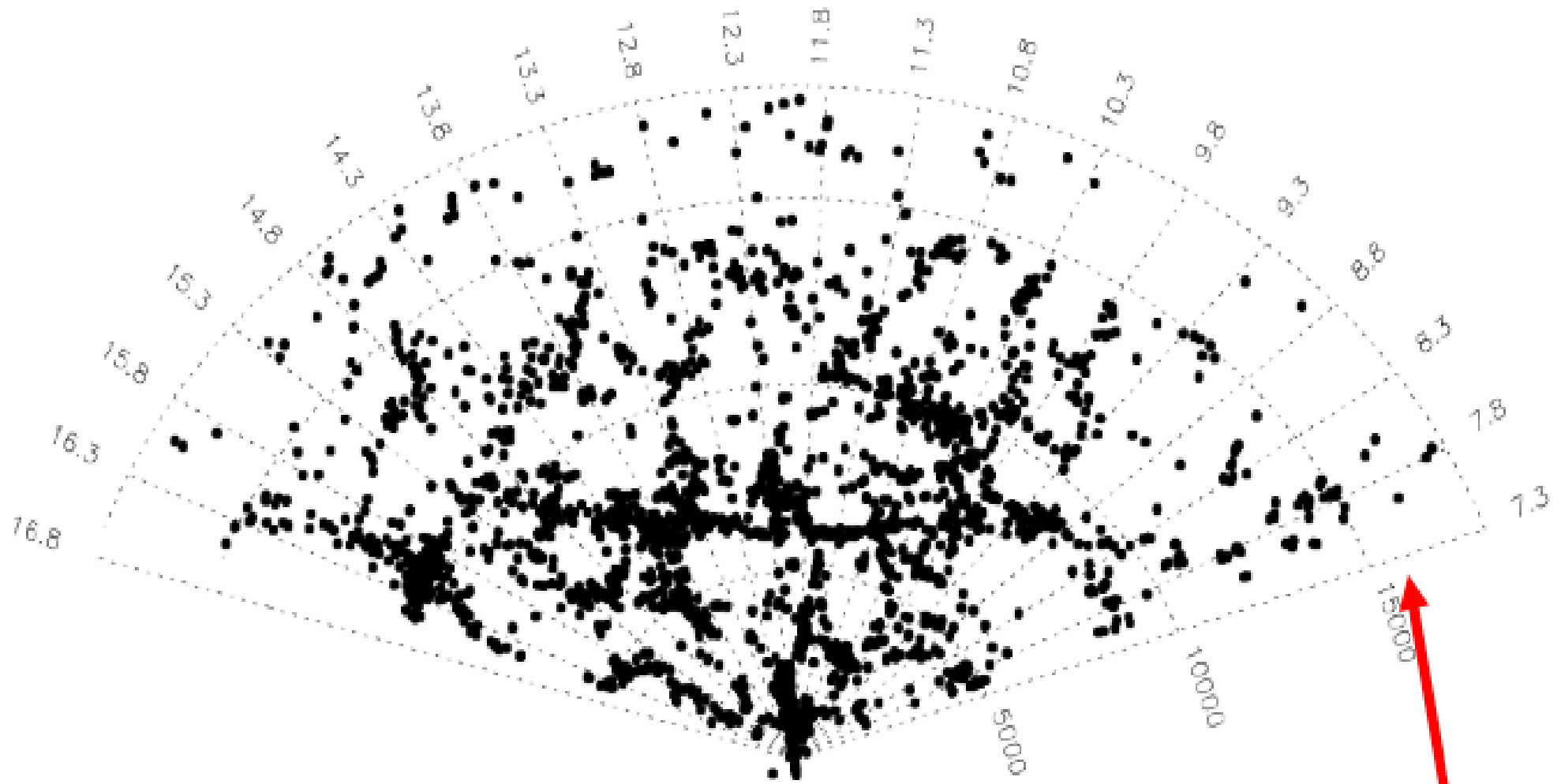
Created by Zolt Frei and James E. Gunn Copyright © 1999 Princeton University Press

Optical



21 cm

# Arecibo redshift survey



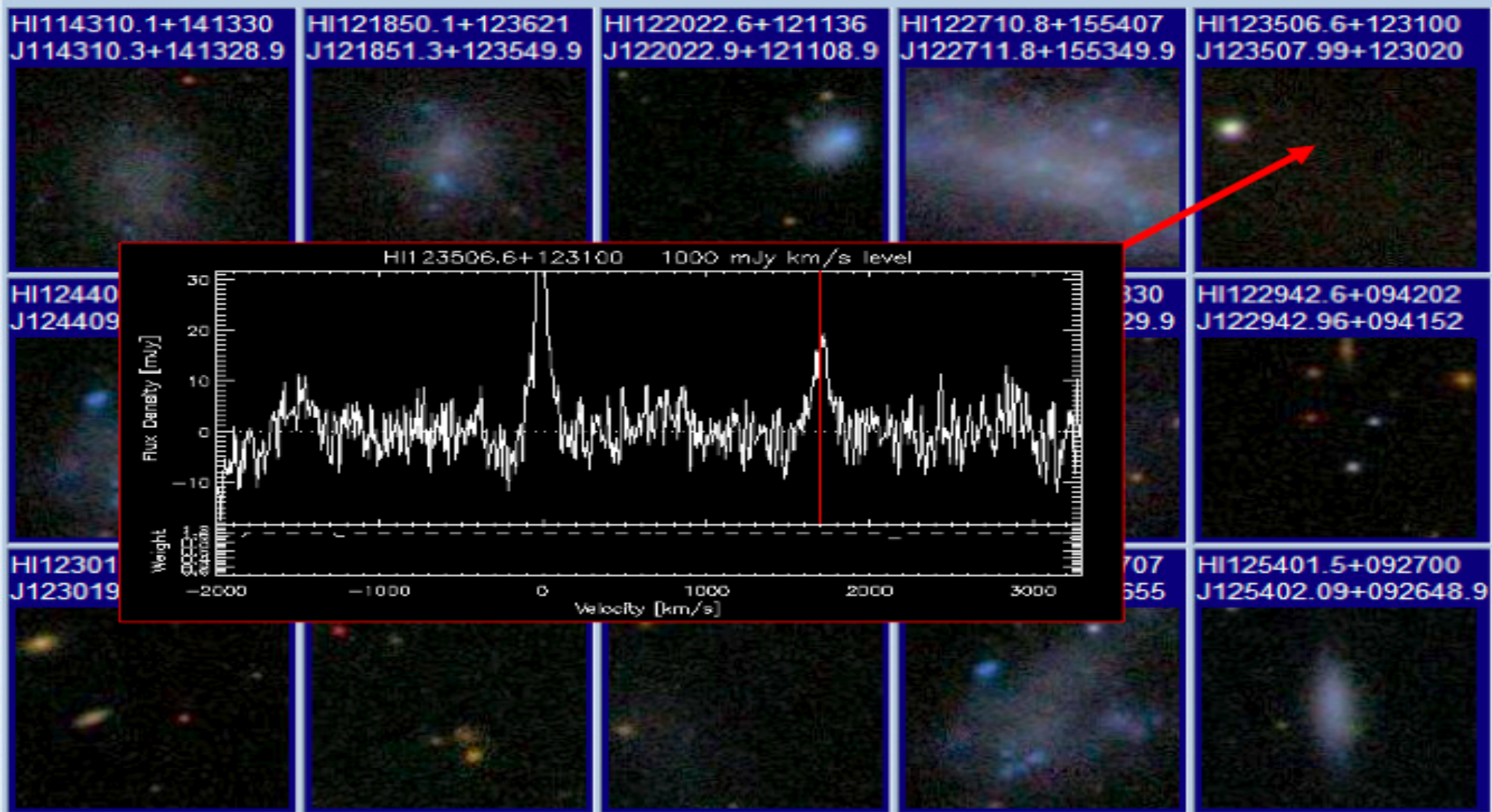
Large scale structure matches  
optical surveys





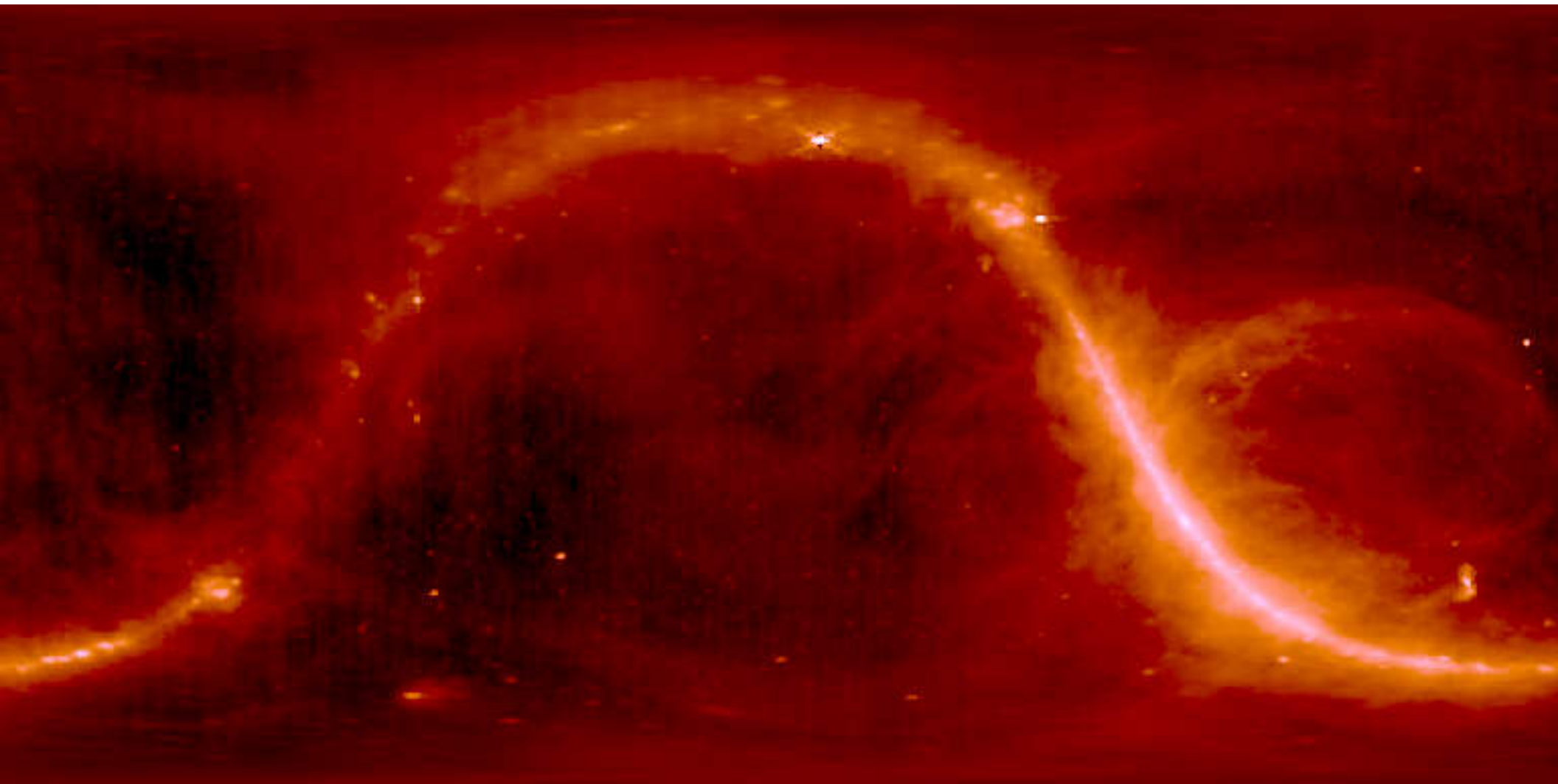
Optical counterparts





69% of HI detections lack  
cataloged optical ID

# Foreground: Galactic Synchrotron

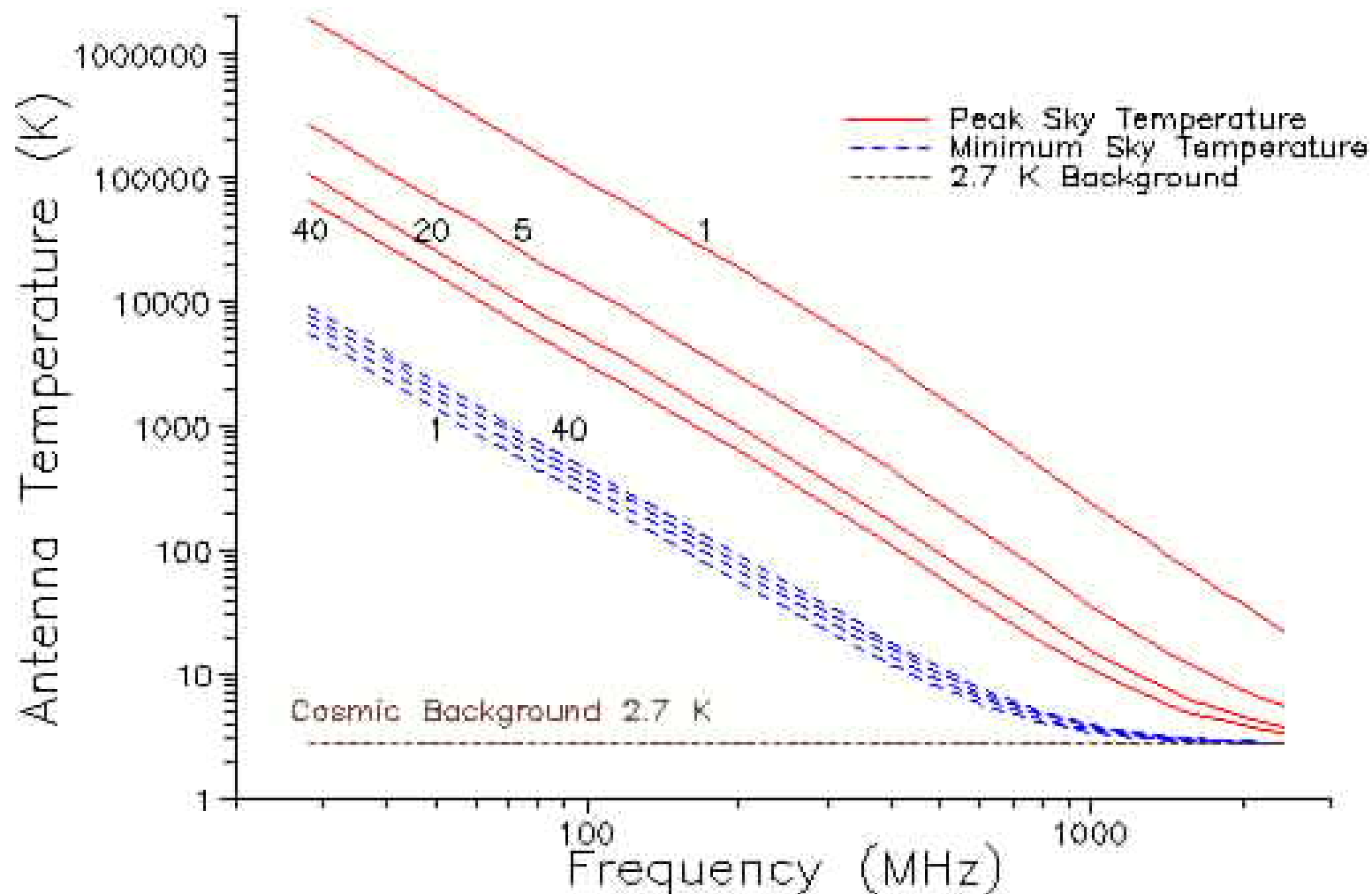


408 MHz

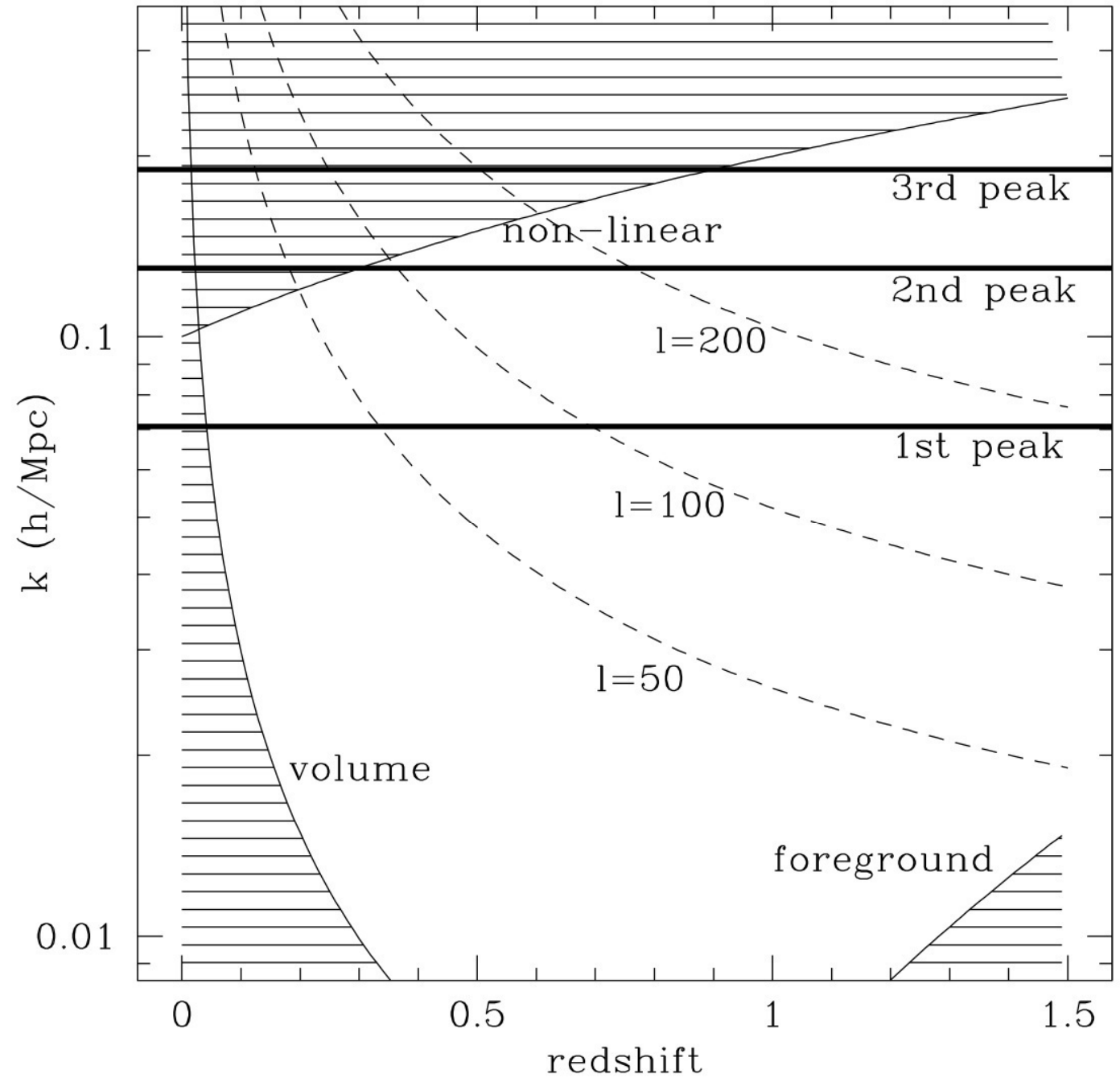


# Synchrotron Spectrum

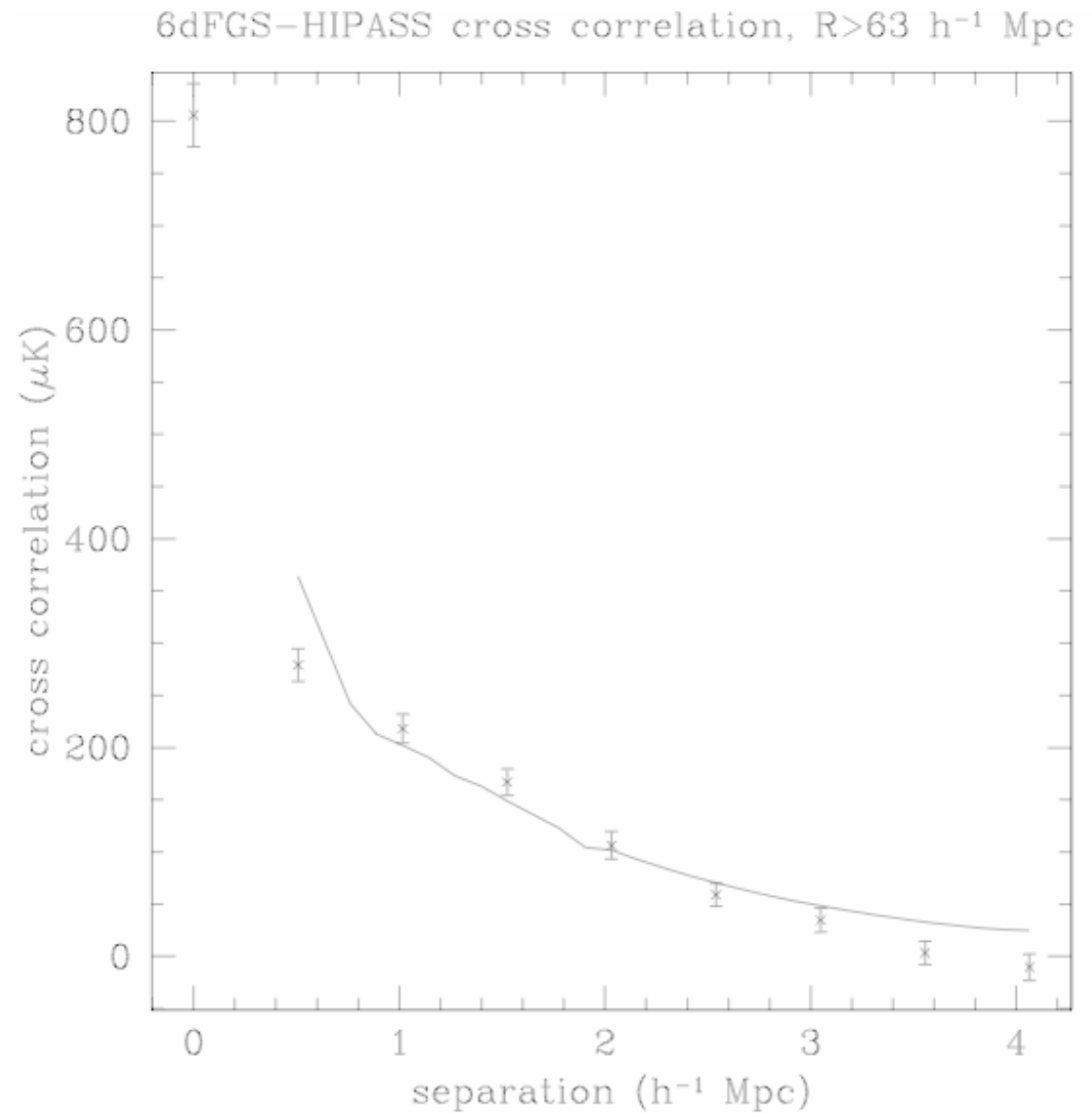
Max & Min Antenna Temperatures vs. Frequency,  
Antenna Beamwidths of 1, 5, 20 & 40 degrees.



Are BAO  
wiggles  
detectable  
via intensity  
mapping?



21 cm glow around  
optical galaxy  
locations has recently  
been detected out to  
3Mpc



# Additional Science

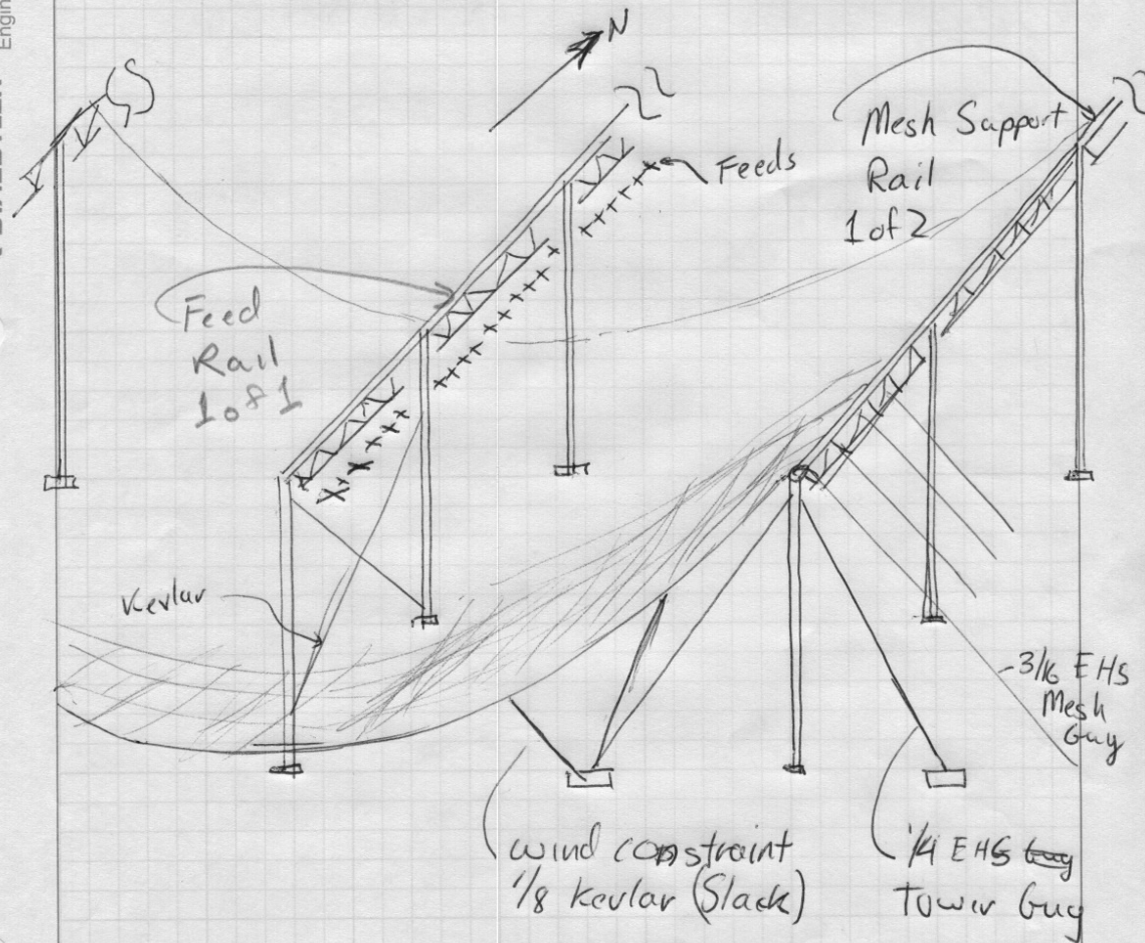
- Find and monitor 1000s of new pulsars-  
-strongly constrain the gravity wave background
- Map galactic magnetic fields
- Search for radio transients
- Study Early Ionization at  $z > 13$  (w/full HSHS)

HI Z Machine

Fixed Reflector  
Cylindrical Reflector

9/13/05 JBP

Approx dimensions:  
Tower height 60'  
Width 200'  
Length 800' - 2000'  
Tower spacing 40'

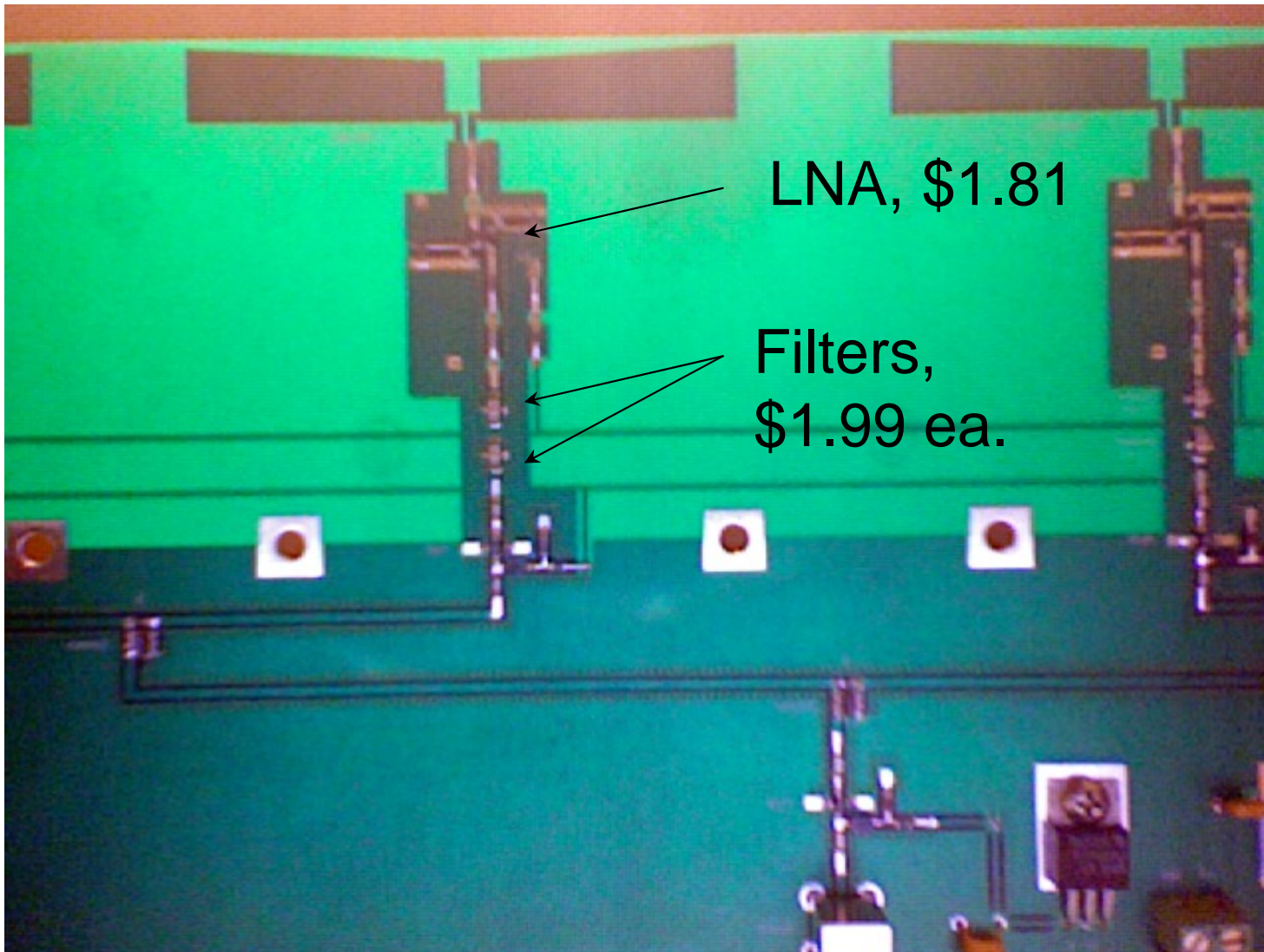


Cylindrical  
reflectors use  
suspended mesh,  
with a line of feed  
points

Reflector Cost:  
~\$20-100/m<sup>2</sup>

Survey  
Speed ~  $A \cdot D$

# Line Feed



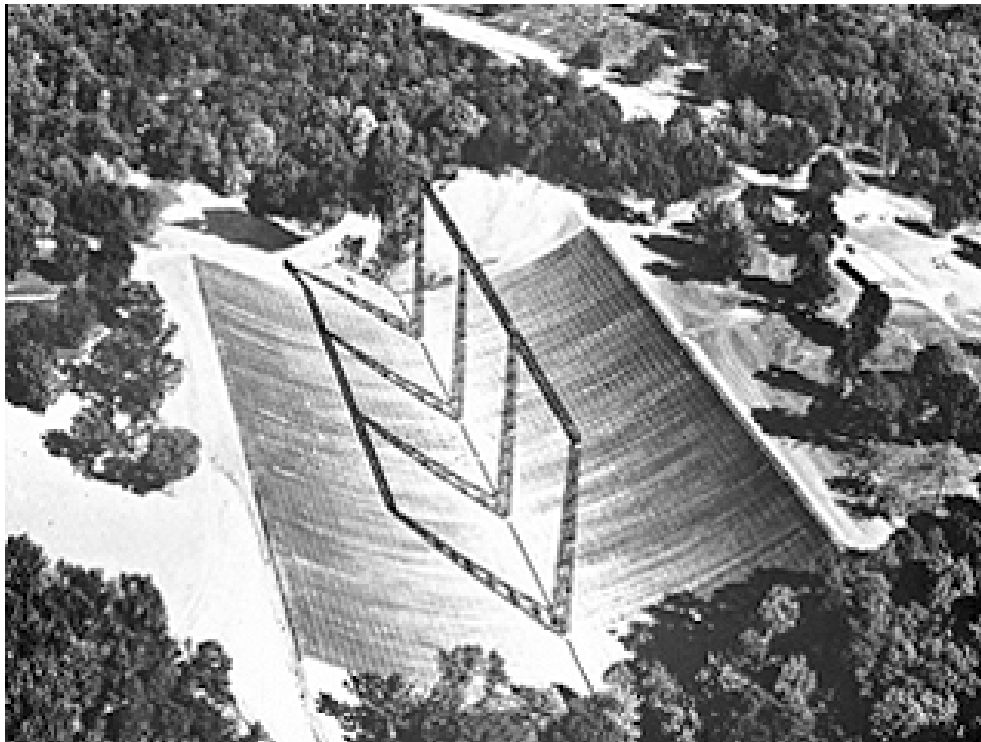


# PAST correlator --- 81 X100 MHz



# Cylinder History

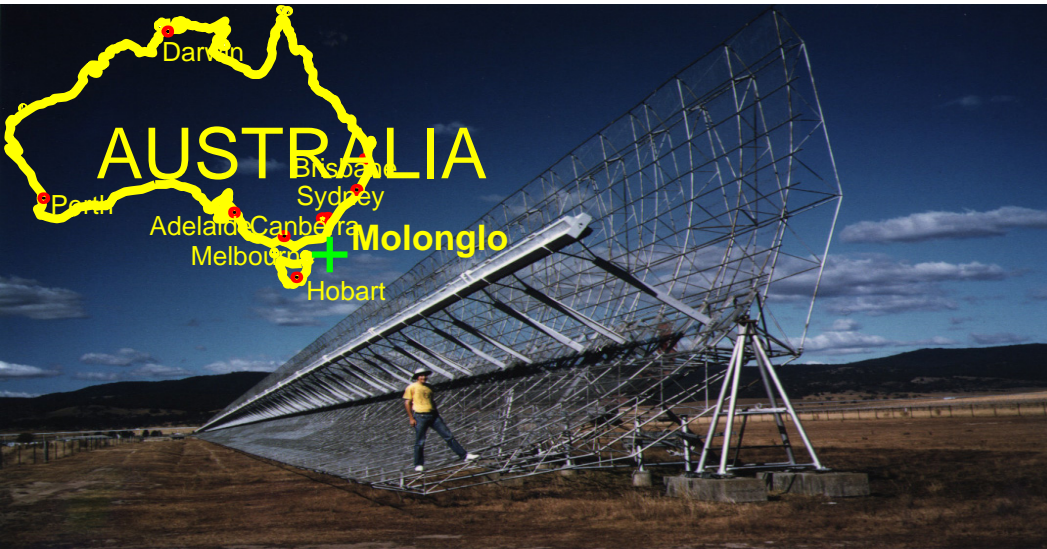
- Popular 1960-1980
- Lost favor with advent of cryogenically cooled pre-amplifiers.
- Room temp amplifiers with 20K noise temp now available.



Illinois 400 ft  
Telescope  
ca. 1960



# Existing cylinders



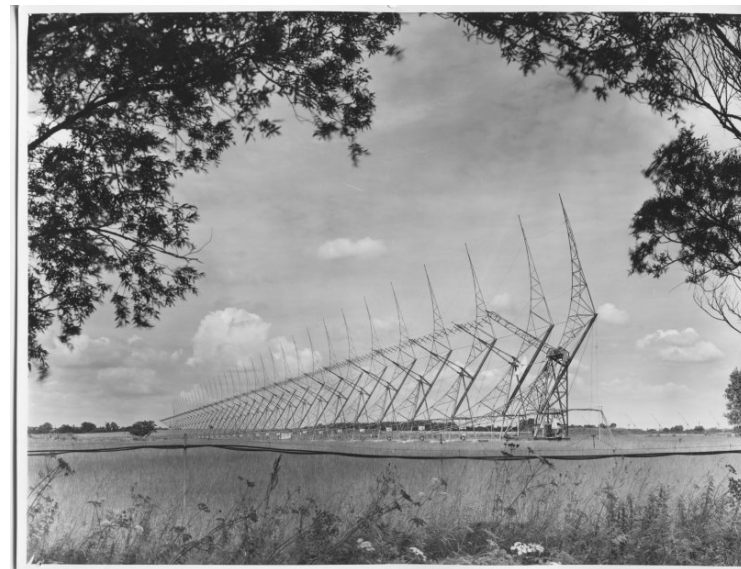
MOLONGLO



NORTHERN CROSS



OOTY

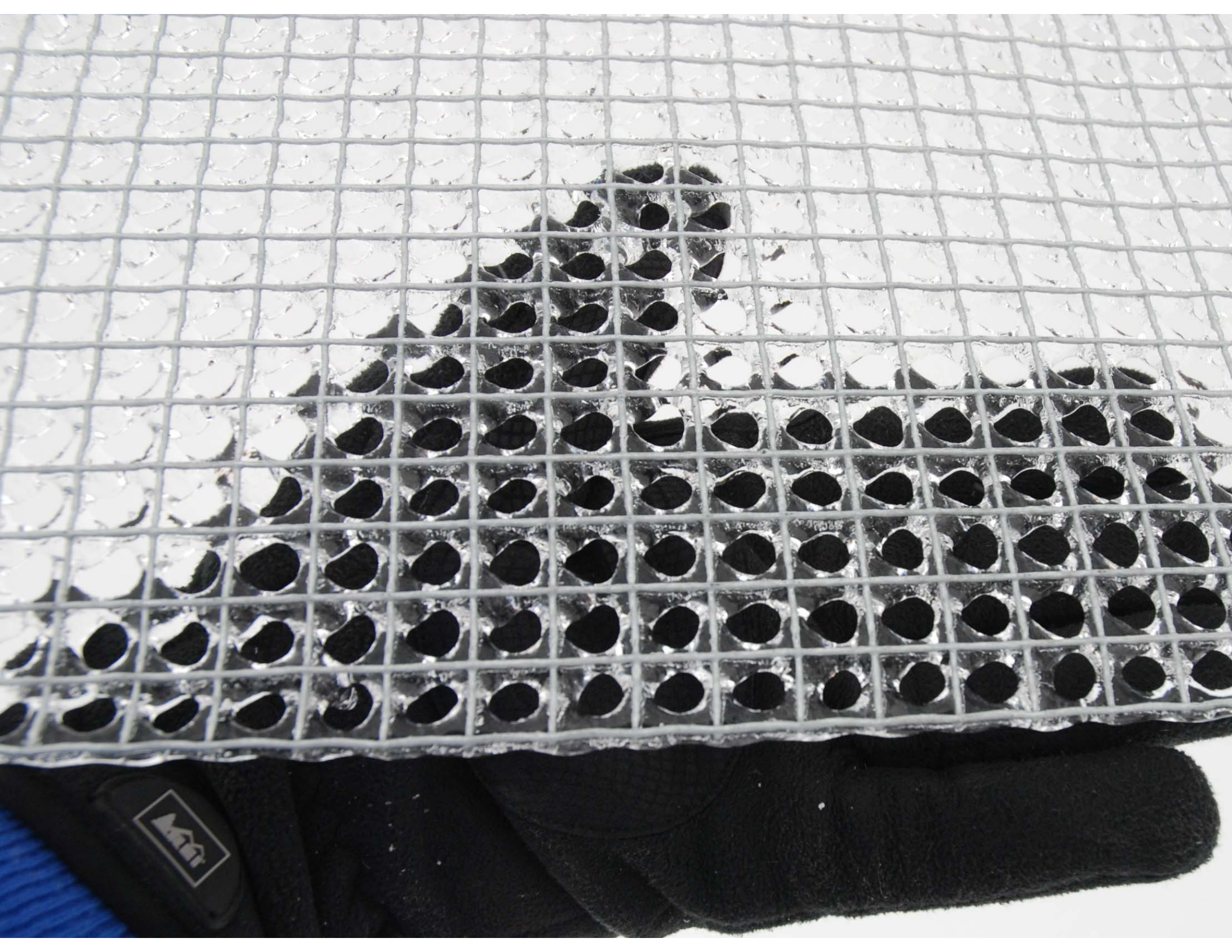


Cambridge









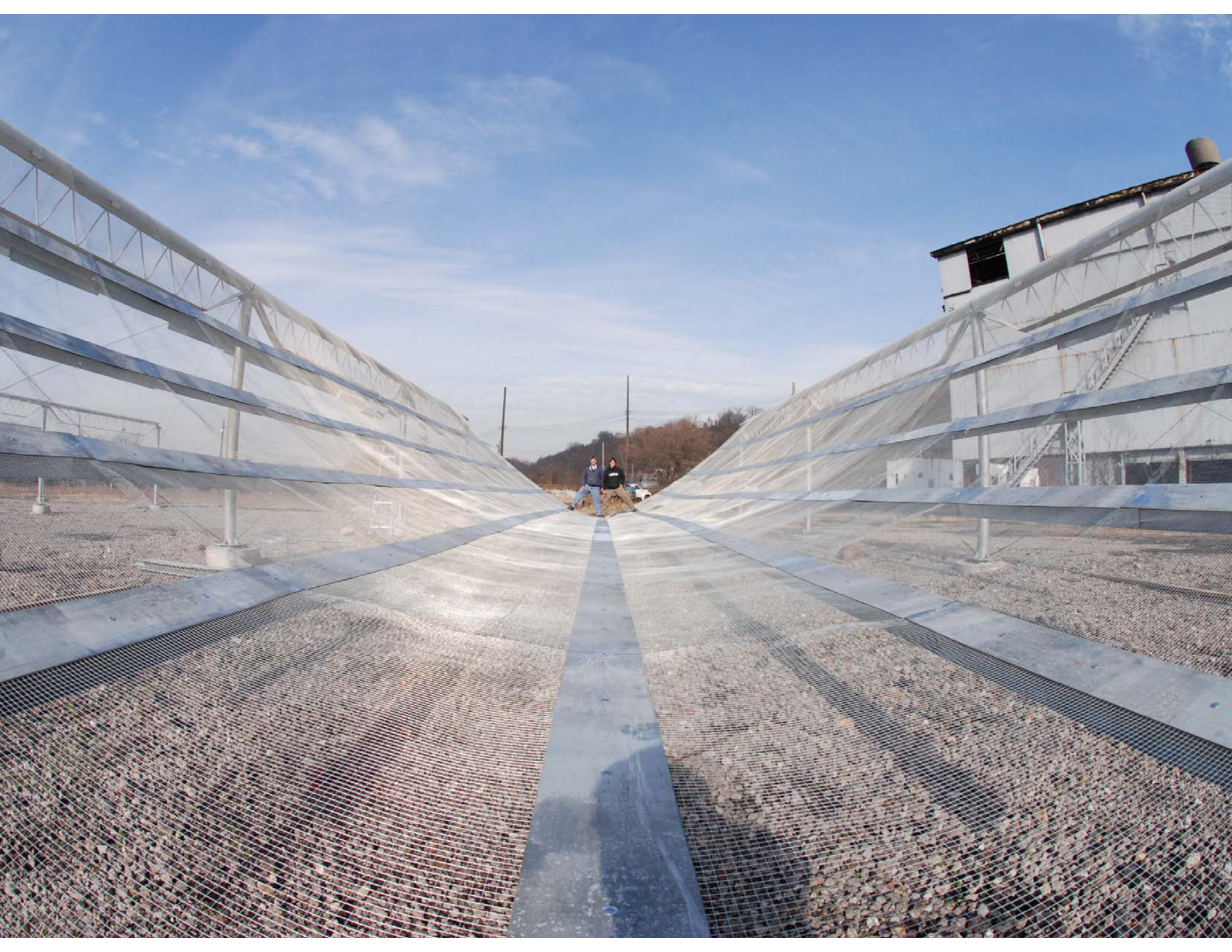




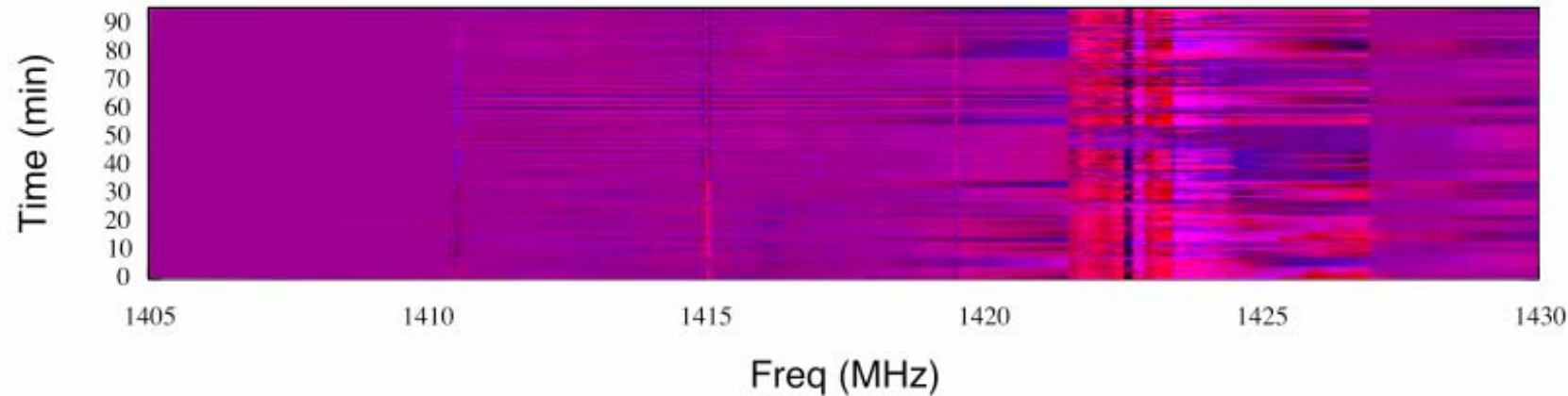




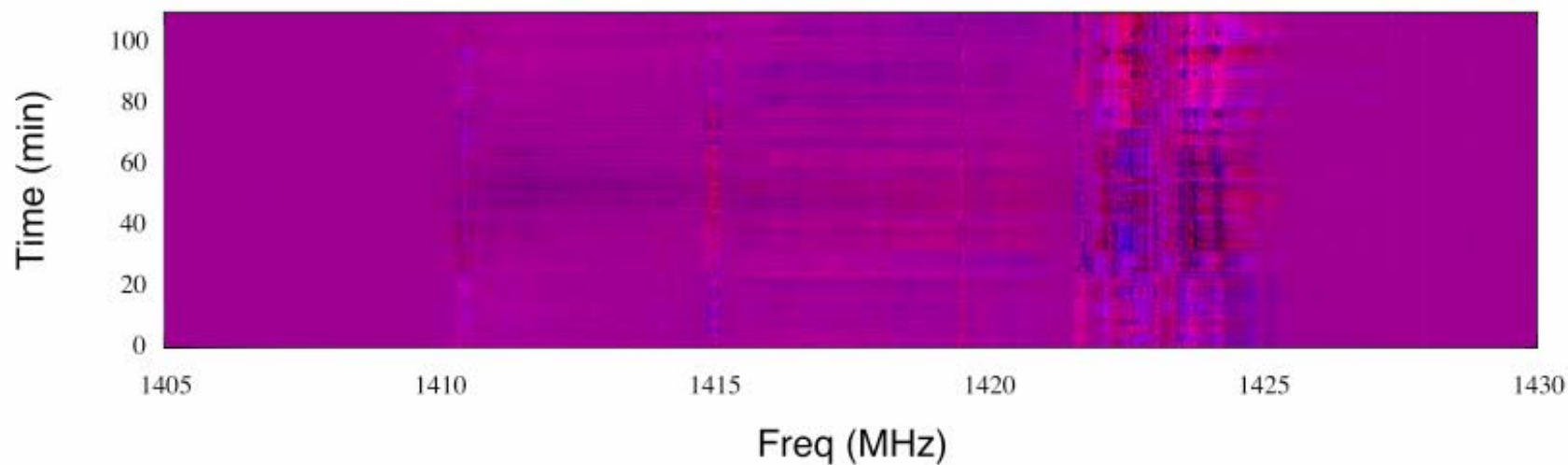




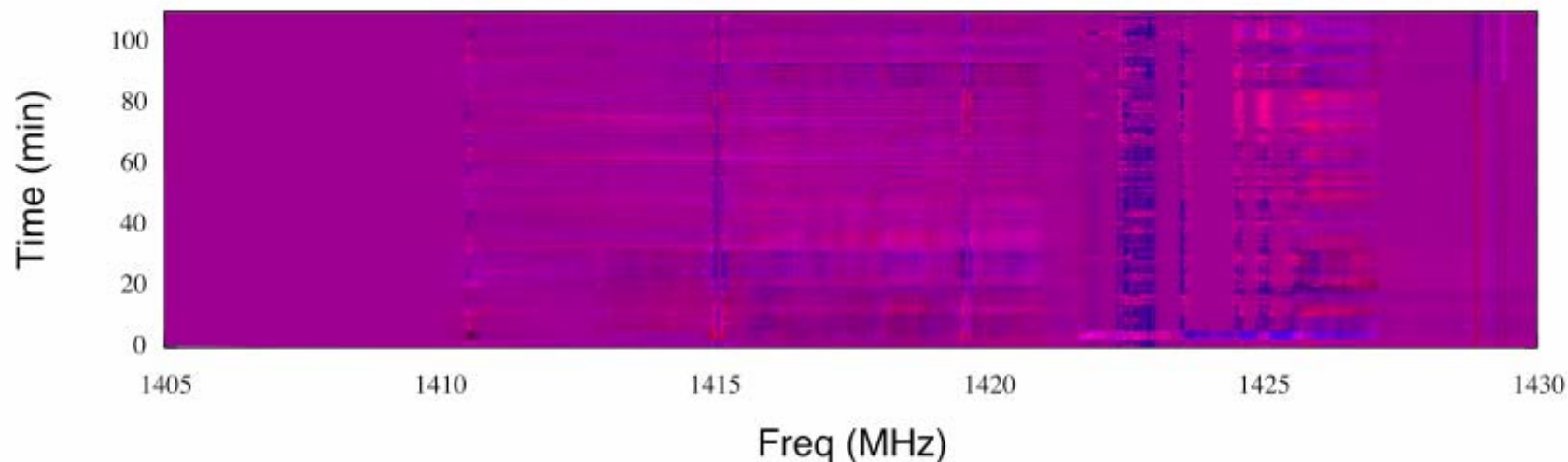




**3/26**  
Started 12:25  
Sun Peak at 61 min



**3/21**  
Started 12:20  
Sun Peak at 67 min



**3/17**  
Started 12:20  
Sun Peak at 68 min

# Next steps

- Study FFT beam forming on Pgh cylinders
- Whitepaper on Systematics
  - Telescope internal reflections
  - Faraday rotation
- Compare cost and systematics for
  - Dipole arrays
  - Cylinder arrays
  - Parabolic dish arrays
  - Large single dish
- Build a 3DIM instrument at a quieter site



# Concluding assertions

- Using off the shelf technology, a redshift survey telescope can be built for modest cost which will yield  $10^9$  redshifts to  $z \sim 1.5$
- Will cover 100 times the SDSS volume
- Will constrain  $W_1$  to  $\sim 0.1$
- BAO constraint to dark energy may be available using an intensity mapping prototype.