

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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 - Bruce Taylor,
 - Derrick McKee
 - Jim McGee
 - Steve Schweizer

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- Ue-LI Pen (CITA)
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 - Christohpe Magneville
 - Jim Rich
 - 2 FTE engineer

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 - Marc Moniez
 - 2 FTE engineer

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 - Jon Bunton (CSIRO)

Carnegie Mellon

IN2P3
INSTITUT NATIONAL DE PHYSIQUE NUCLEAIRE
ET DE PHYSIQUE DES PARTICULES

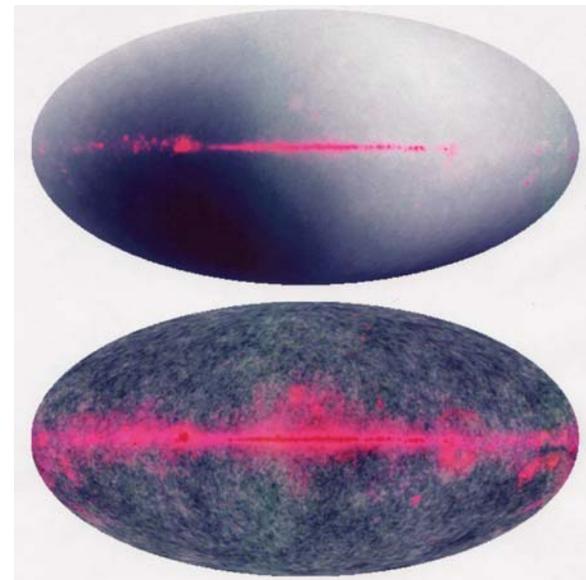
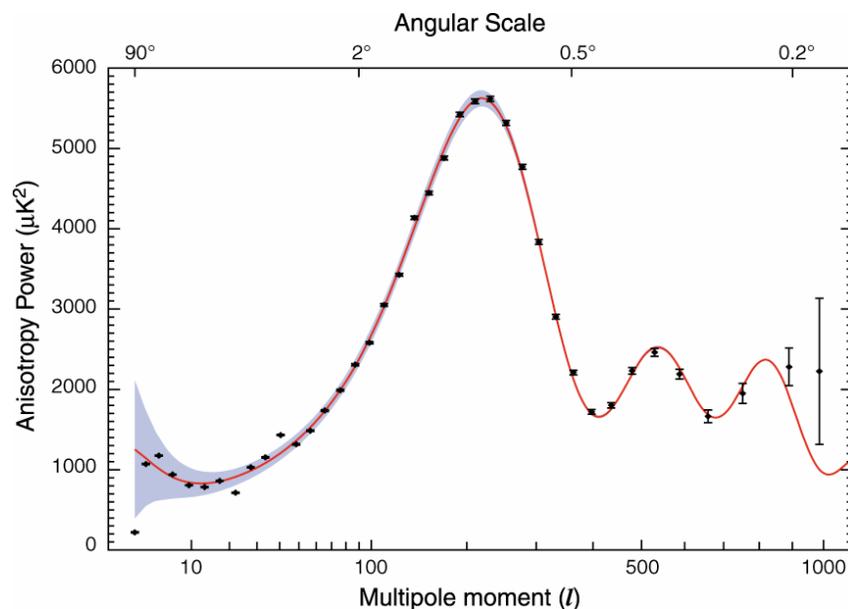


the David &
Lucile Packard
FOUNDATION

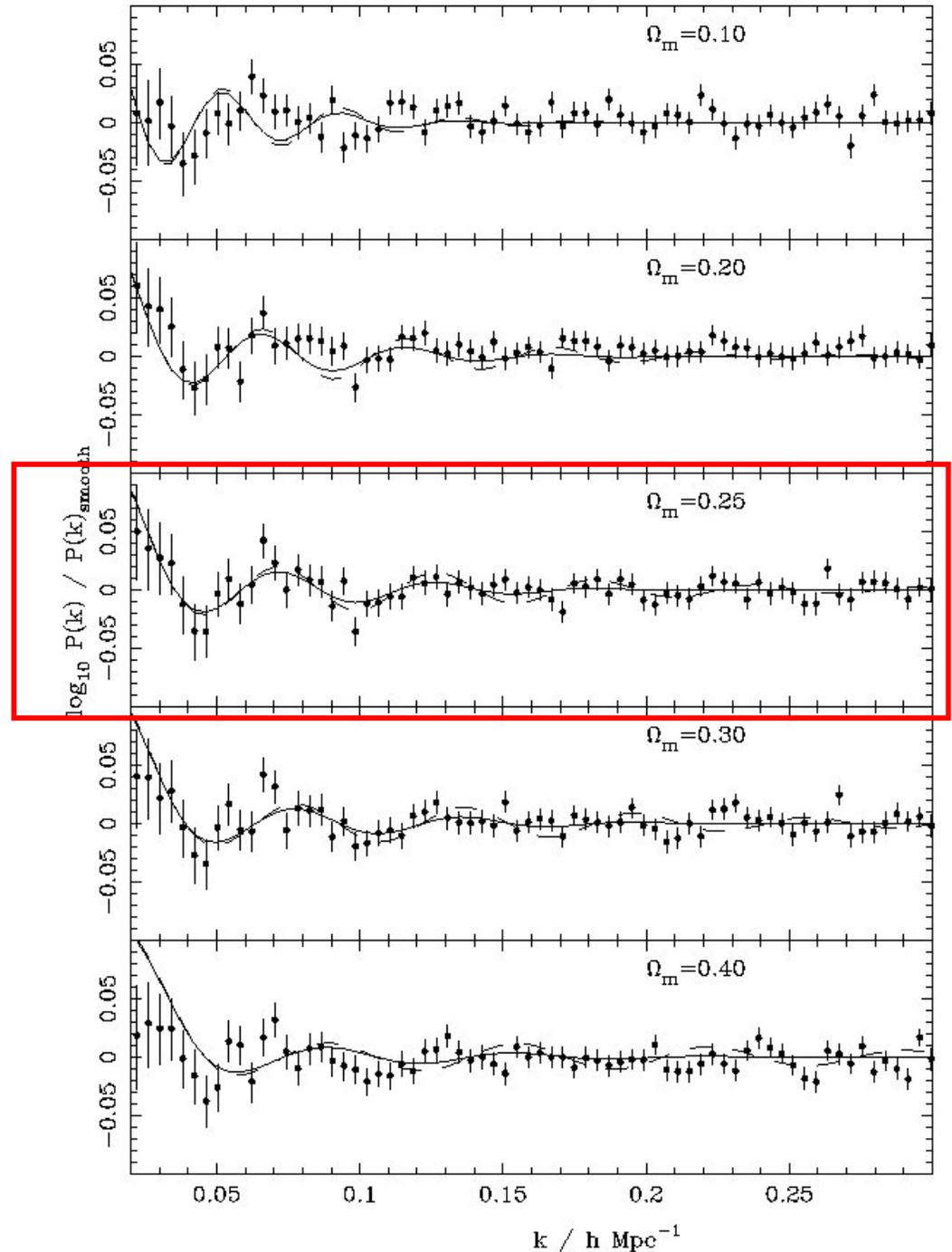
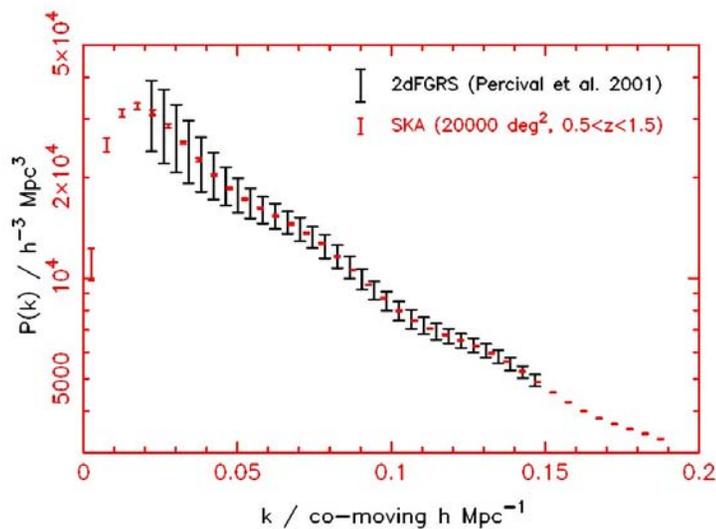


The Universe is Accelerating

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

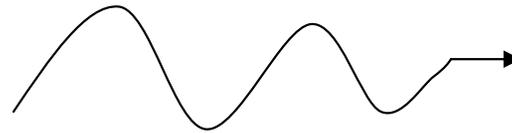
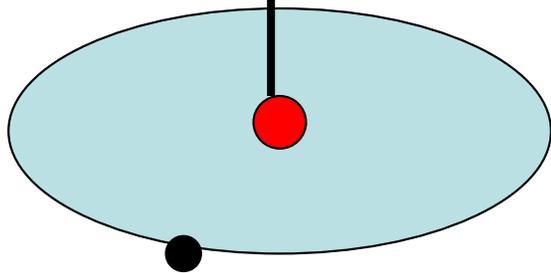


Baryon Wiggles 'Detected' by SDSS and 2df

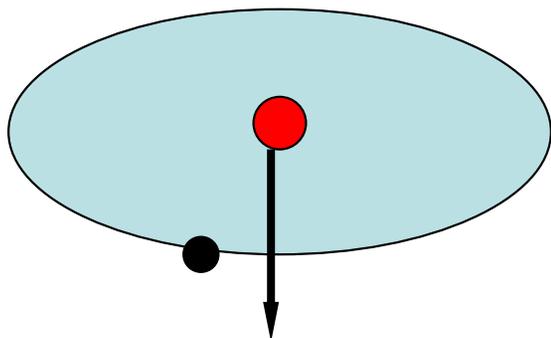


Nuclear Hyperfine Transition of Hydrogen

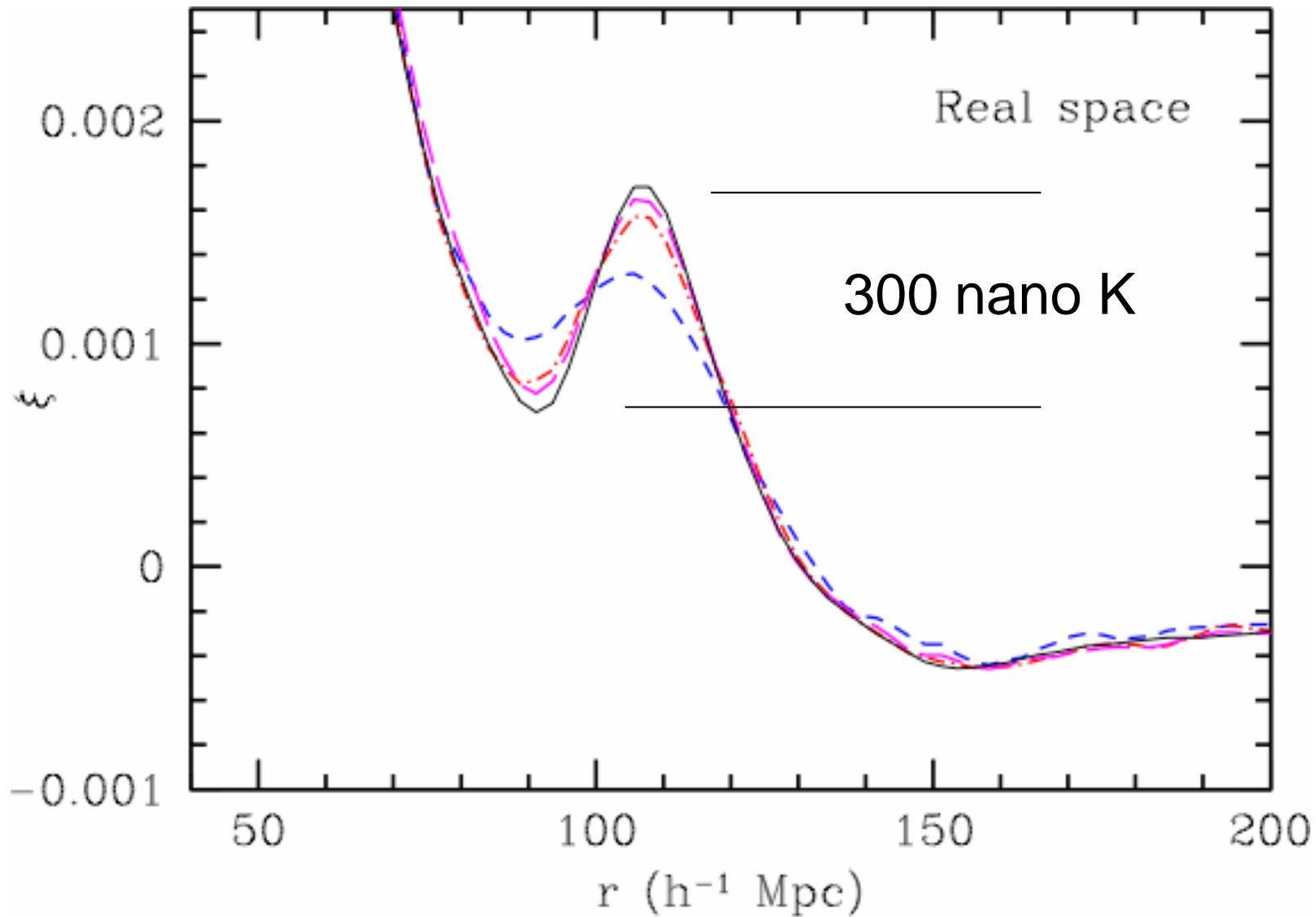
- Cross section small—but hydrogen is abundant



1420 MHz



The BAO peak in autocorrelation



Should we detect individual
galaxies?

Use a galaxy redshift survey?

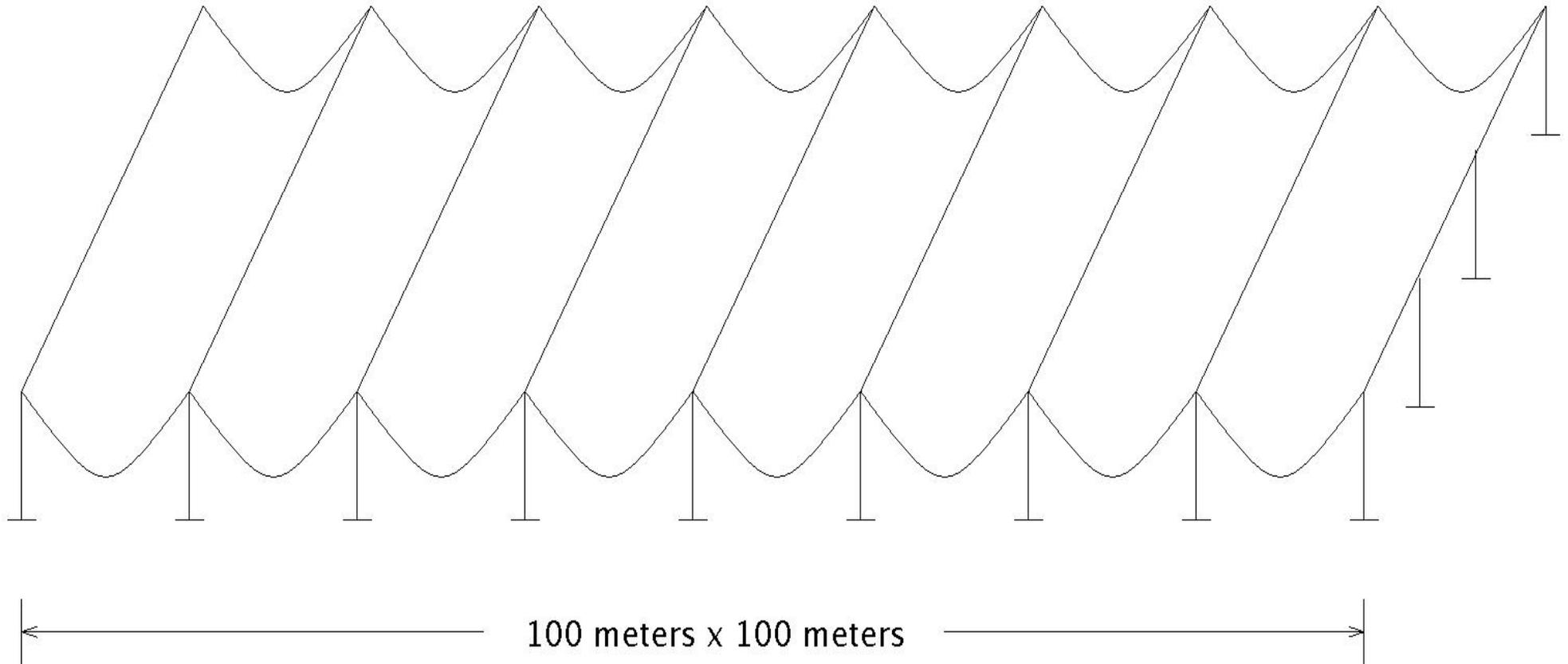
Or

Use the 3-d intensity field directly?

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

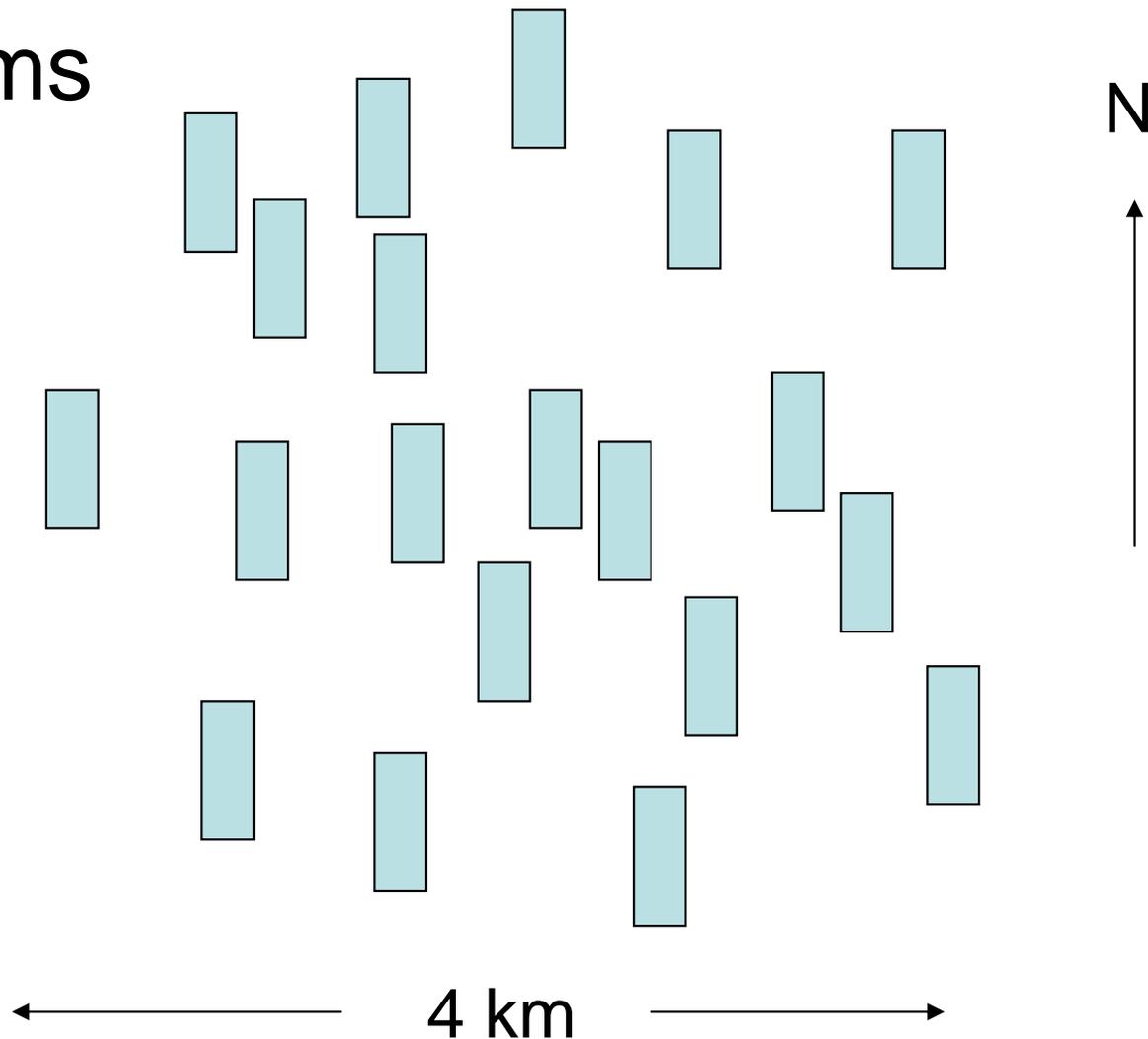
- What if we just collect all emission in
~20Mpc cells and map that (3DIM)?
- This requires only 10,000 sq meters

A Possible 3DIM Layout



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

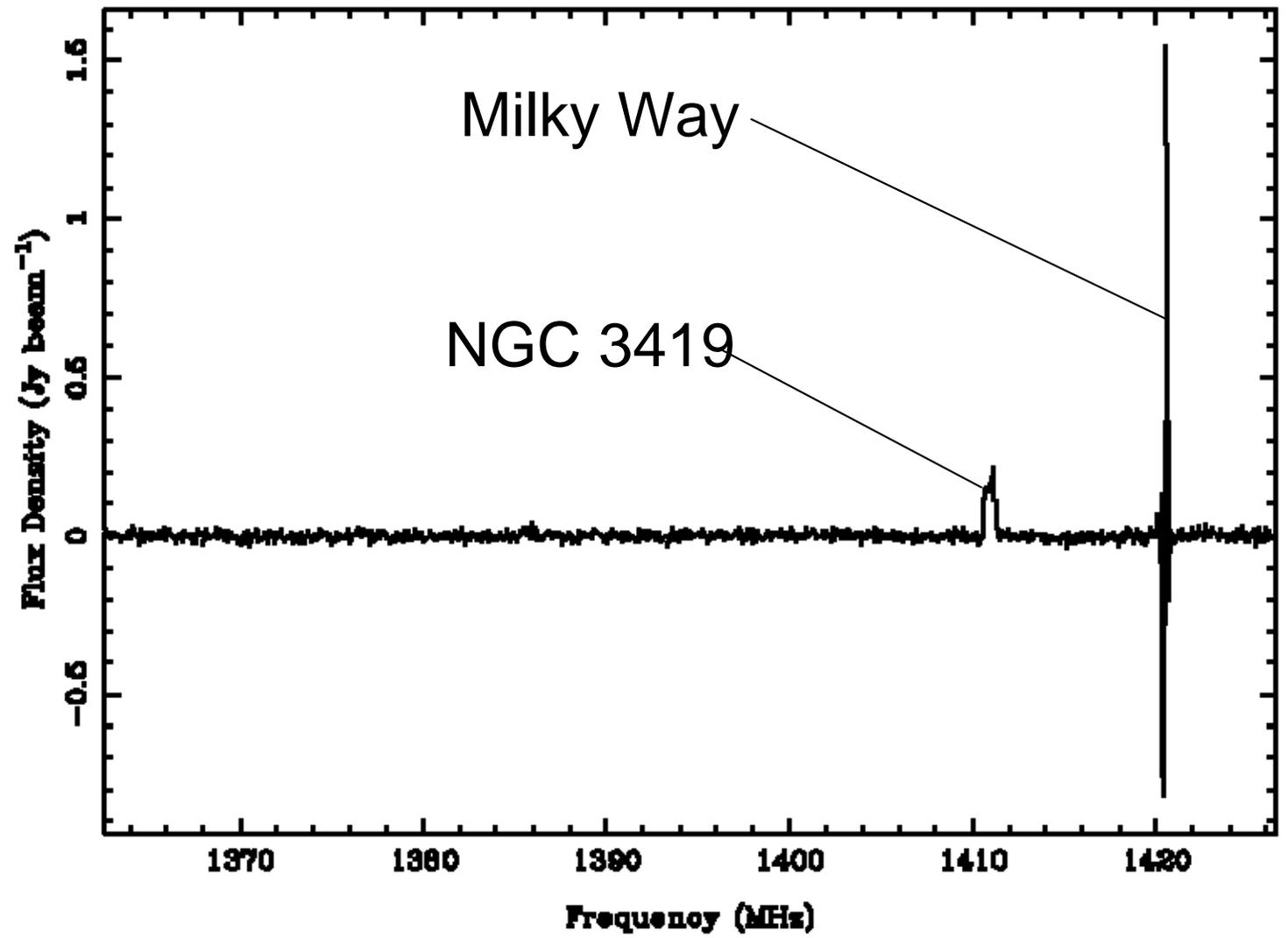
- Line feeds at foci used to create 1024 beams

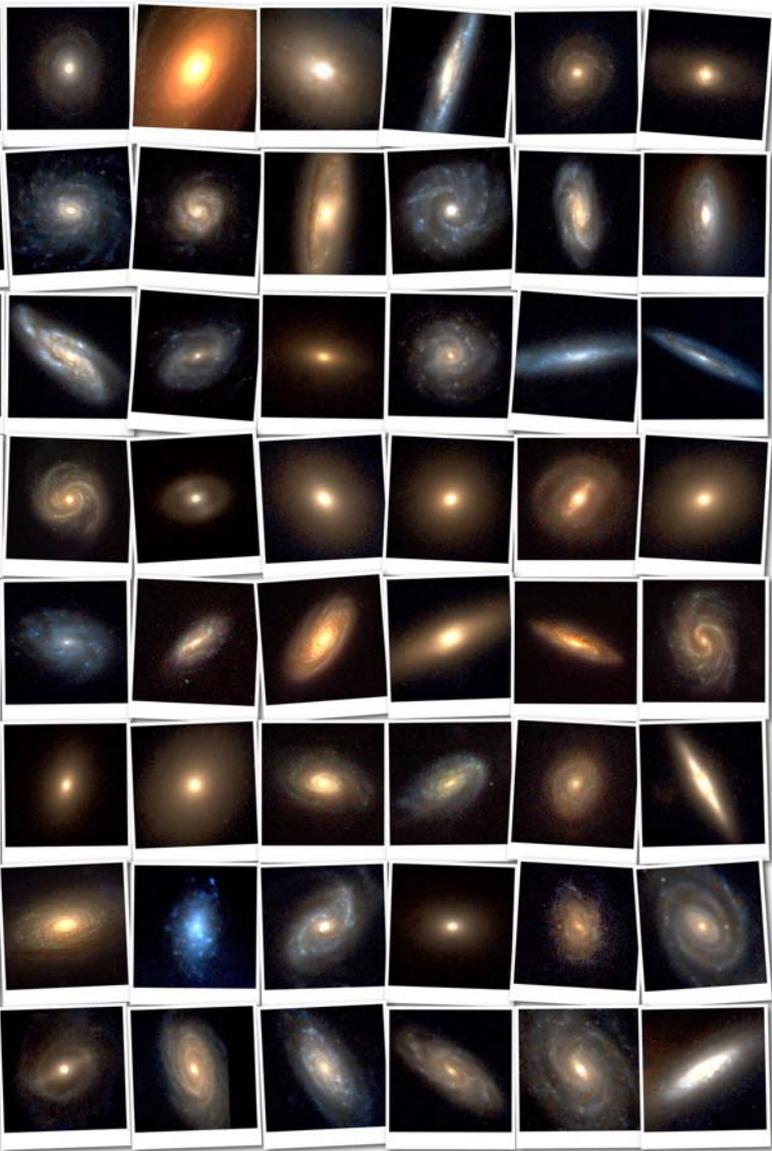


Object: H004
Requested: 10:04:00.00 -80:29:08.00
Actual : 10:03:37.98 -80:23:18.98
Equinox : J2000

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

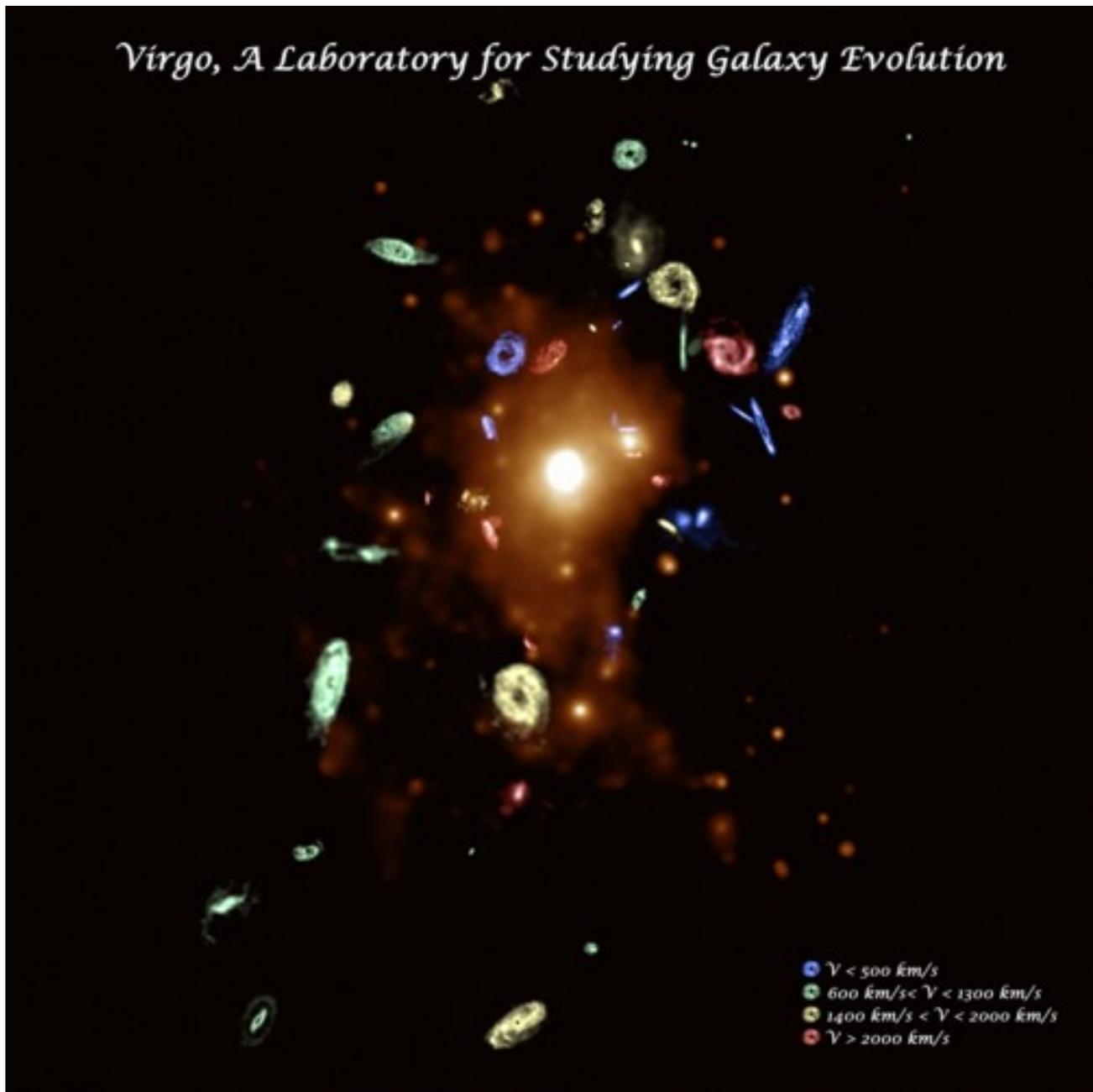
Data from
Parkes
Telescope





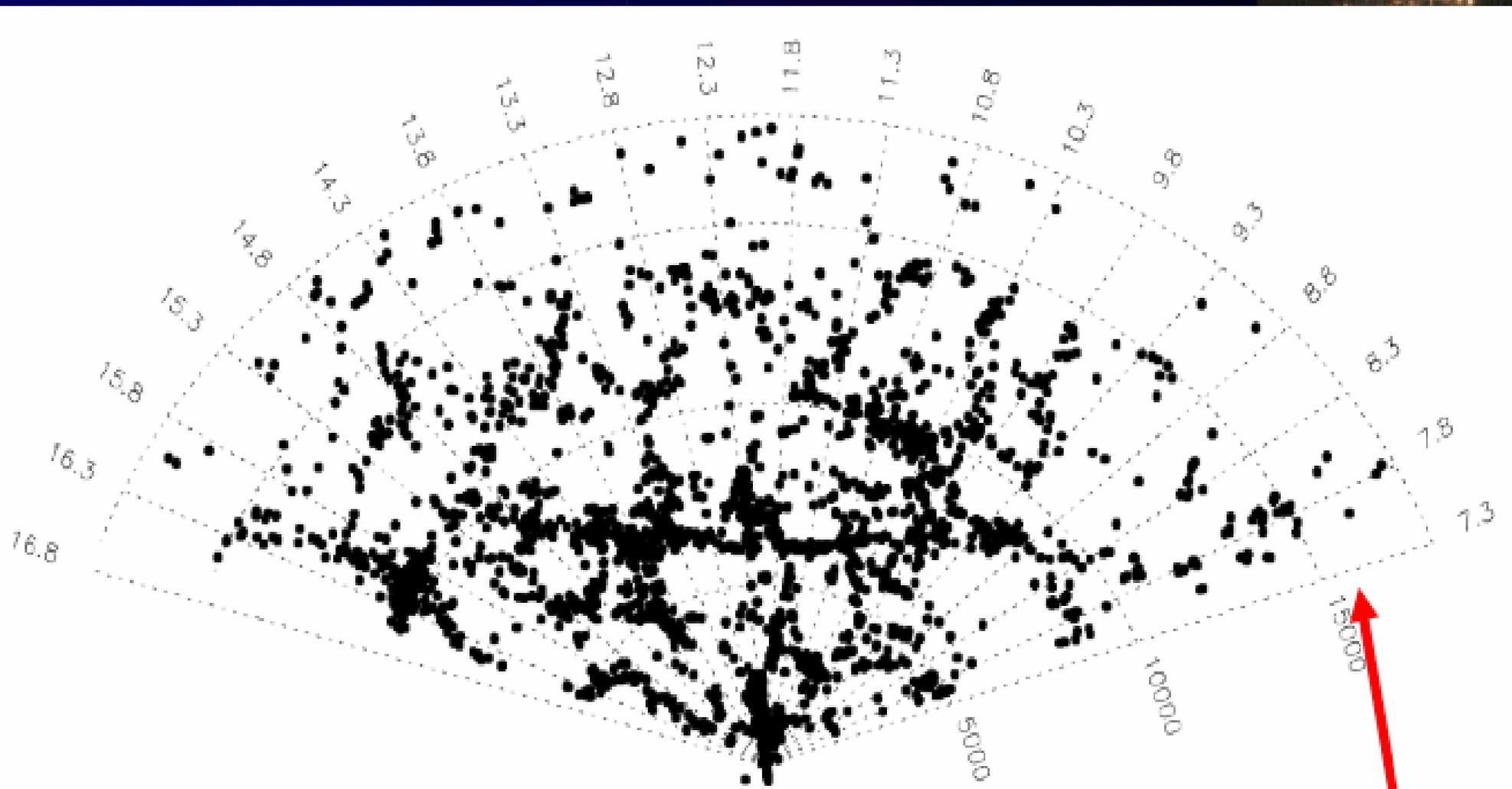
Created by Zolt Frei and James E. Gunn Copyright © 1999 Princeton University Press

Optical



21 cm

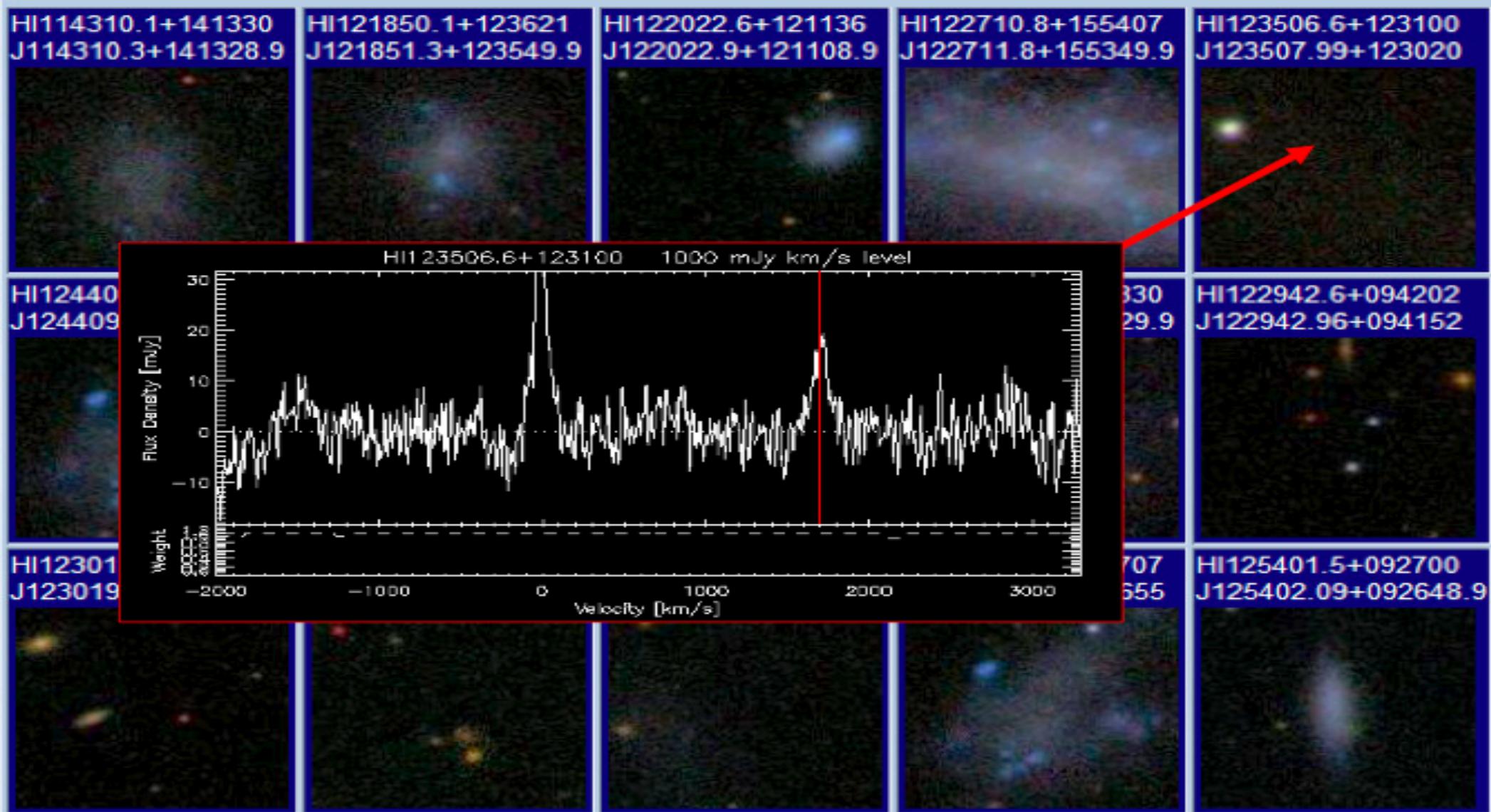
Arecibo redshift survey



Large scale structure matches
optical surveys

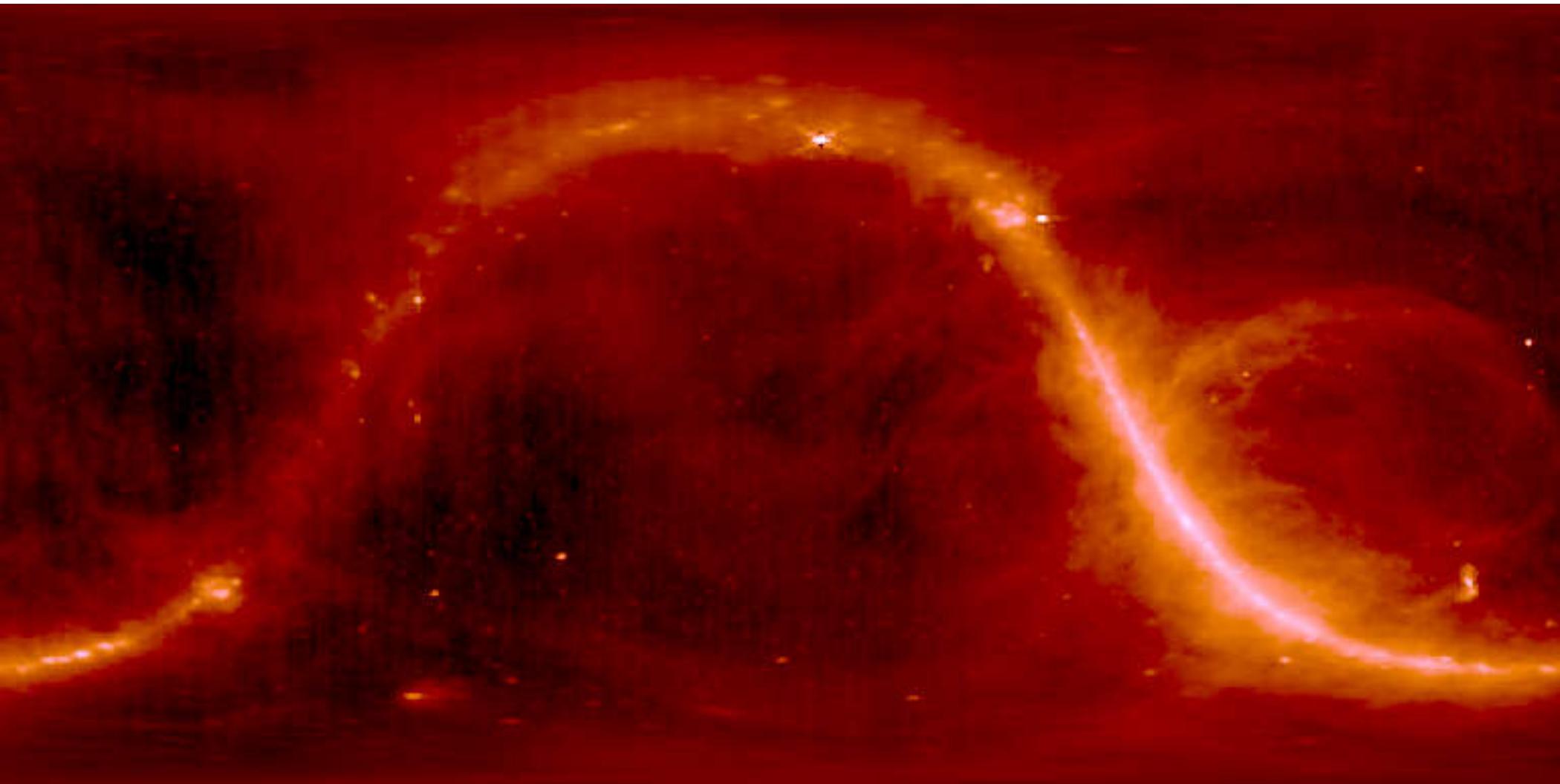


Optical counterparts



69% of HI detections lack cataloged optical ID

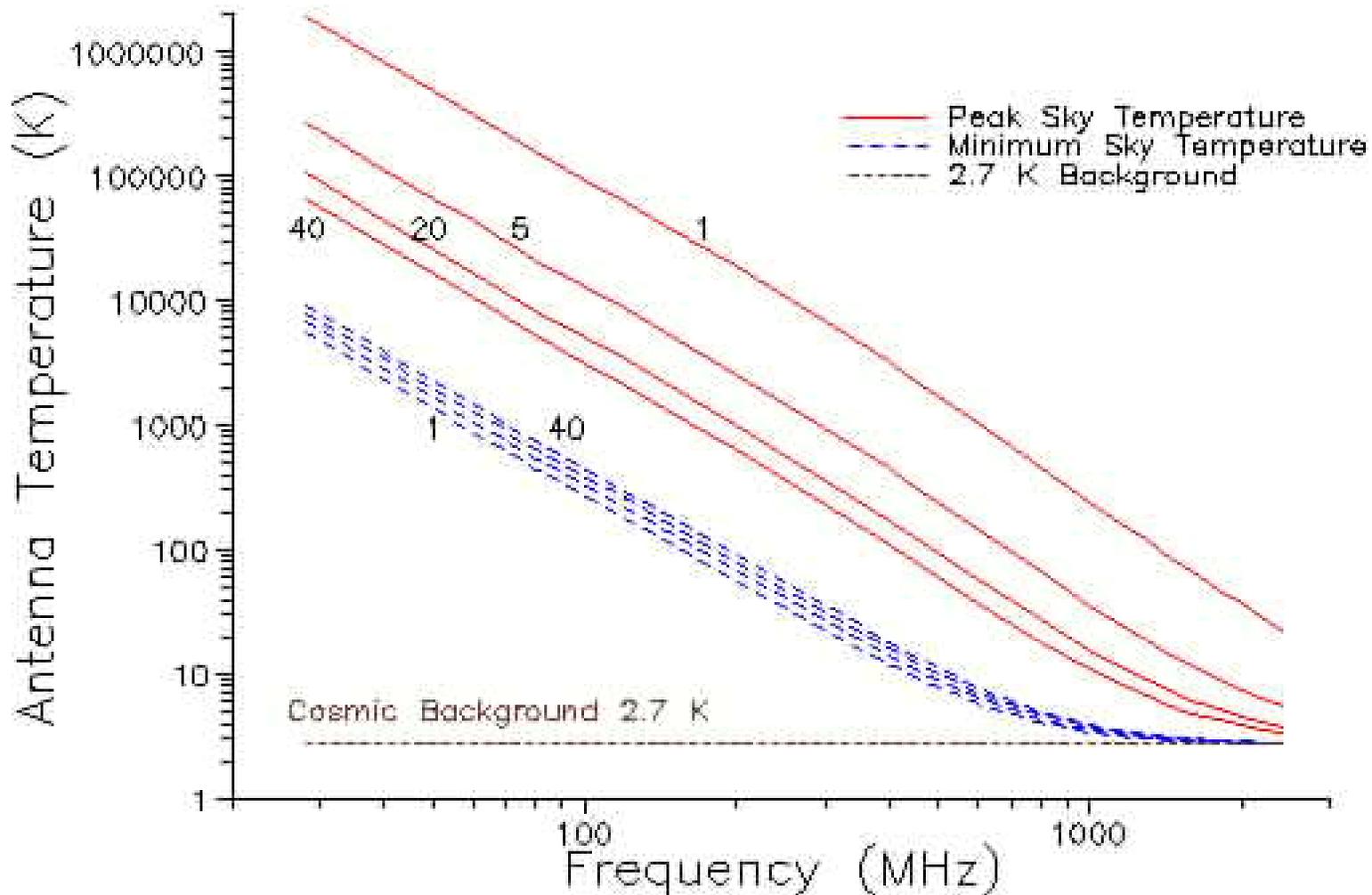
Foreground: Galactic Synchrotron



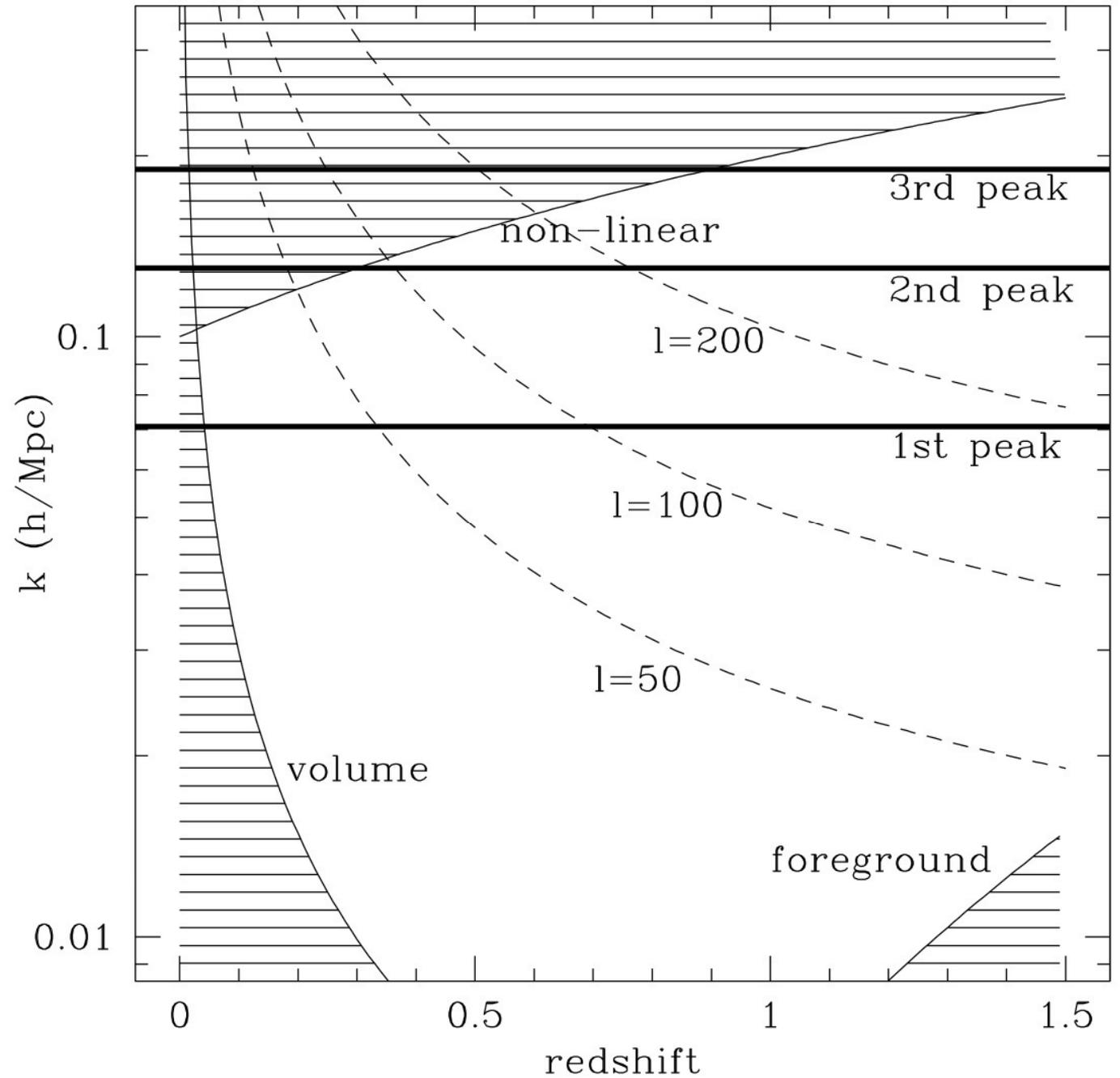
408 MHz

Synchrotron Spectrum

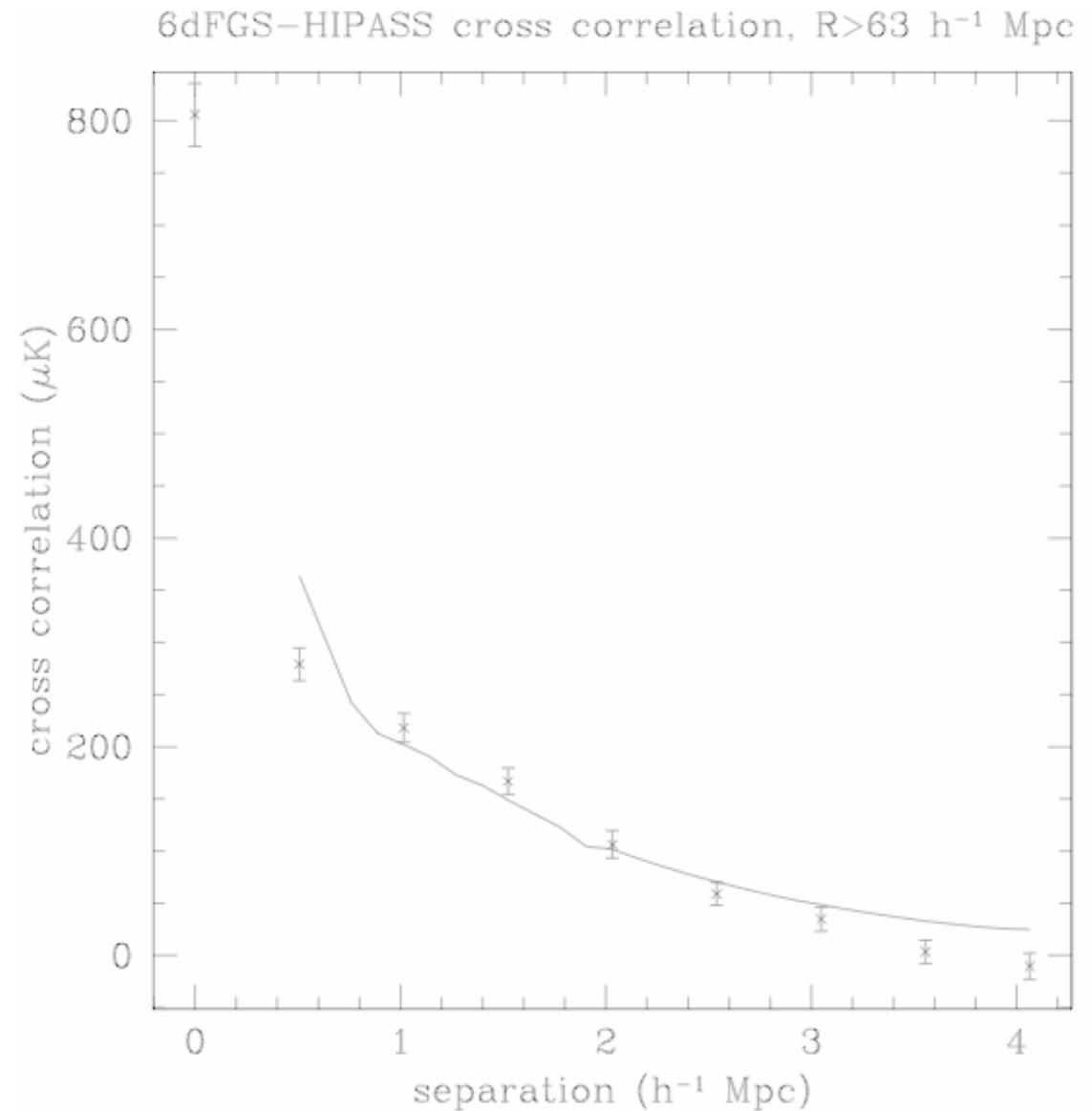
Max & Min Antenna Temperatures vs. Frequency,
Antenna Beamwidths of 1, 5, 20 & 40 degrees.



Are BAO
wiggles
detectable
via intensity
mapping?



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

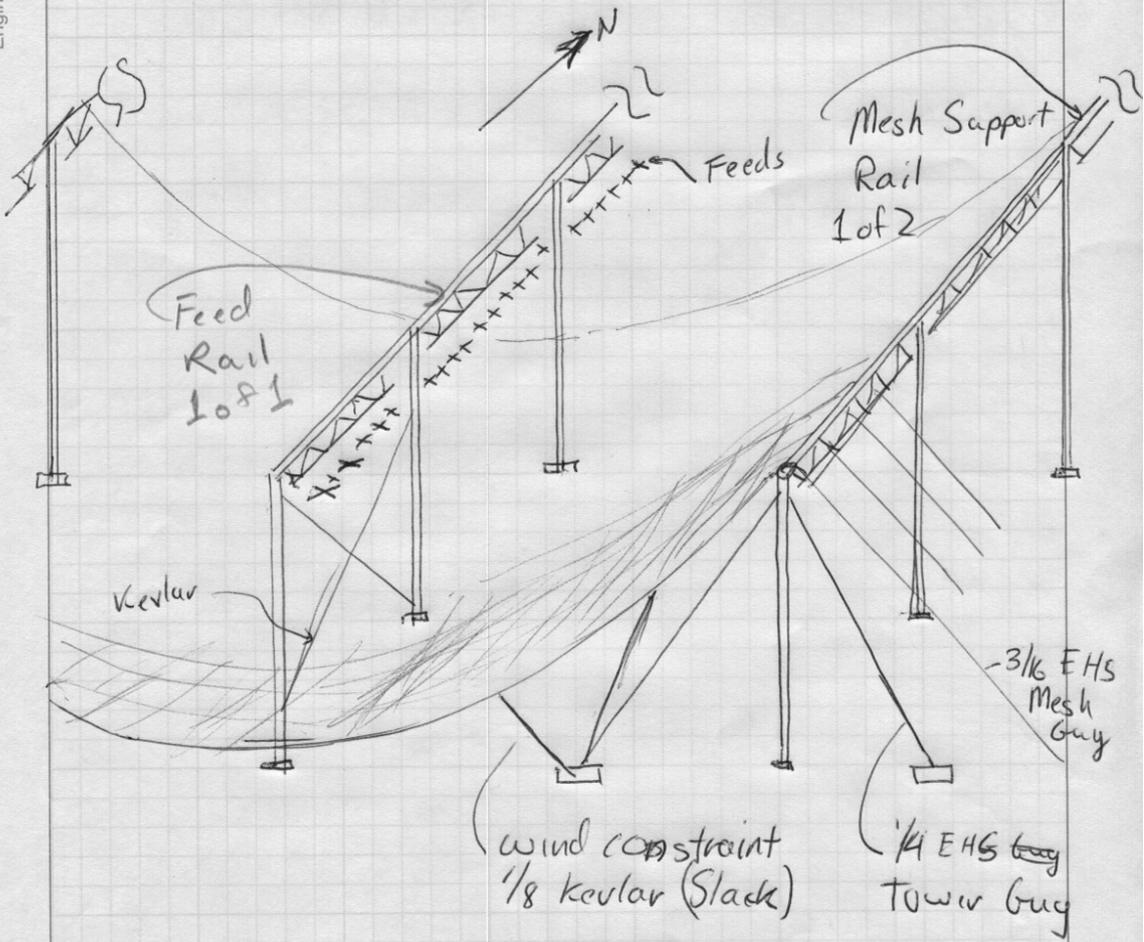


Additional Science

- 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 JBB

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

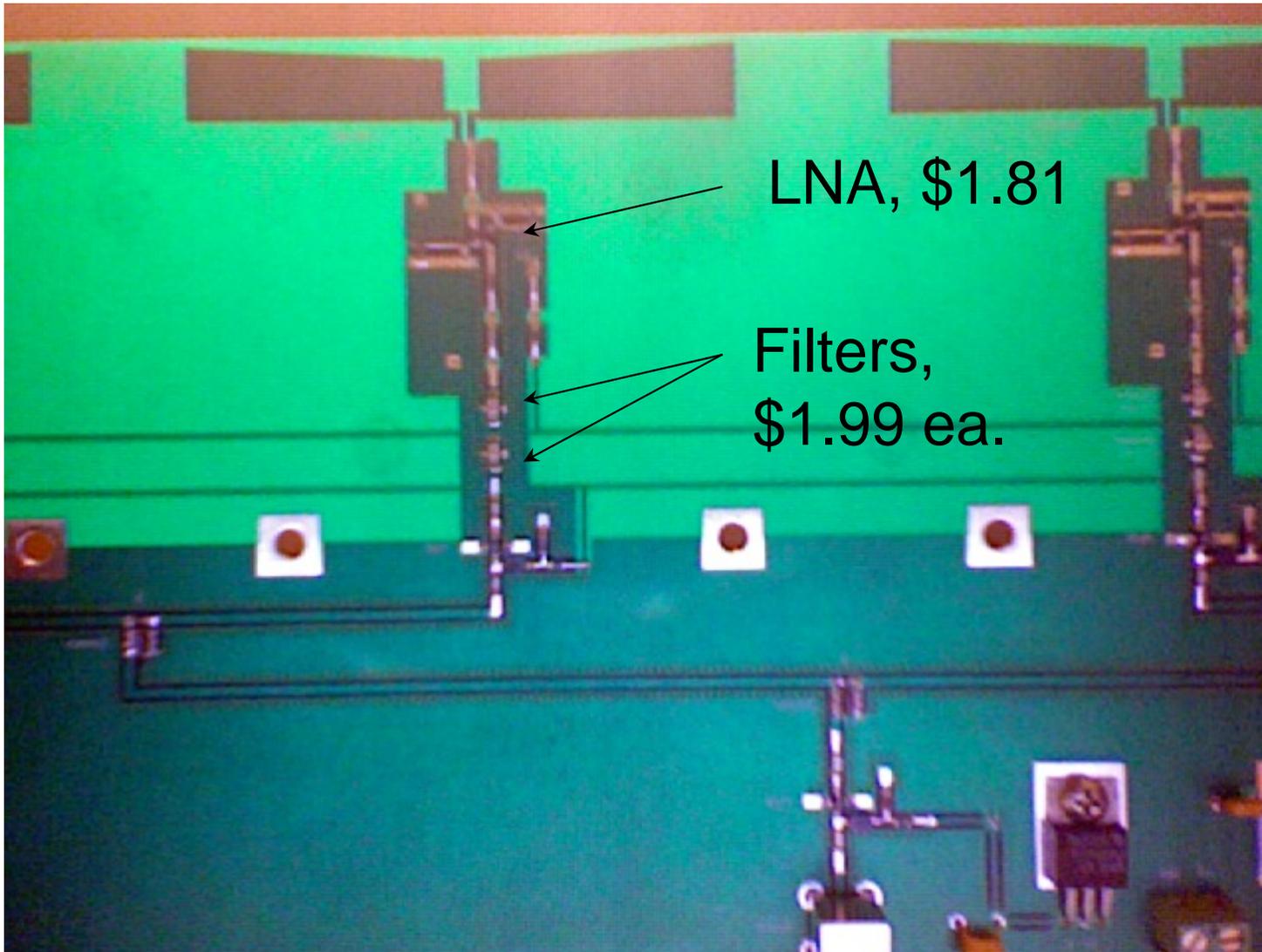


Cylindrical reflectors use suspended mesh, with a line of feed points

Reflector Cost:
~\$20-100/m²

Survey Speed ~ A * D

Line Feed

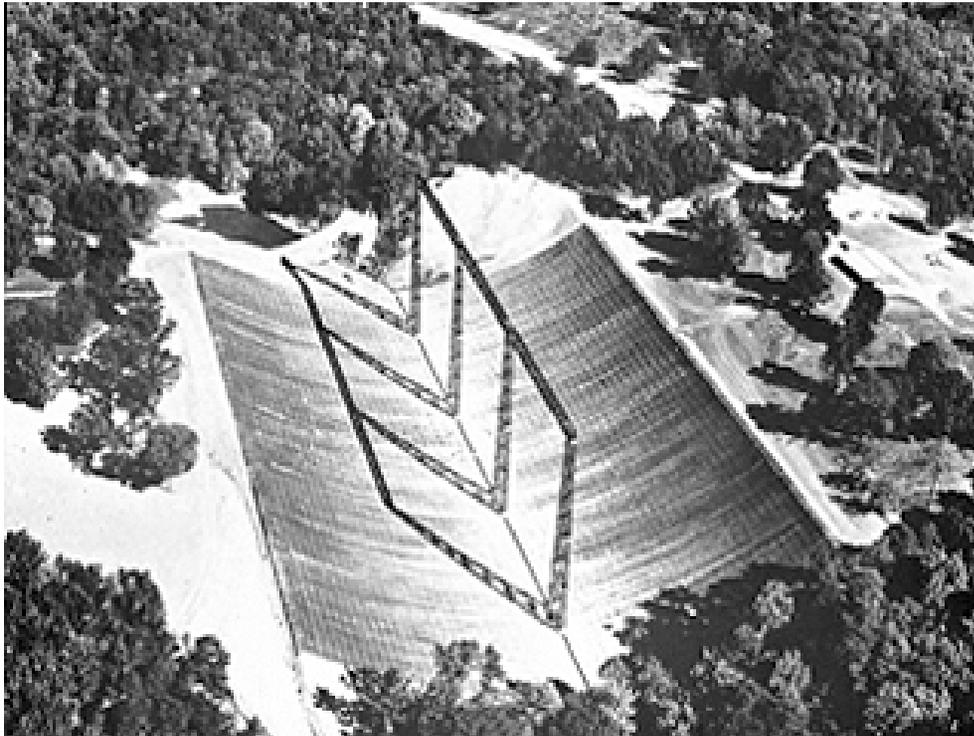


PAST correlator --- 81 X100 MHz



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



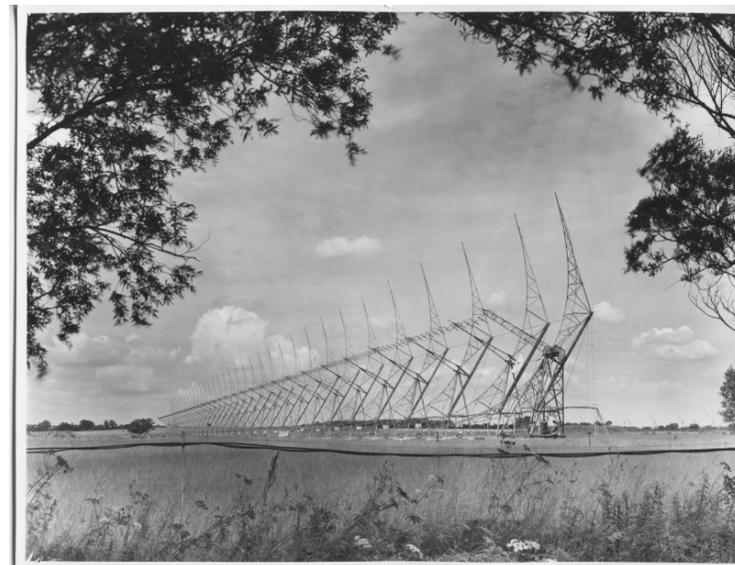
MOLONGLO



NORTHERN CROSS

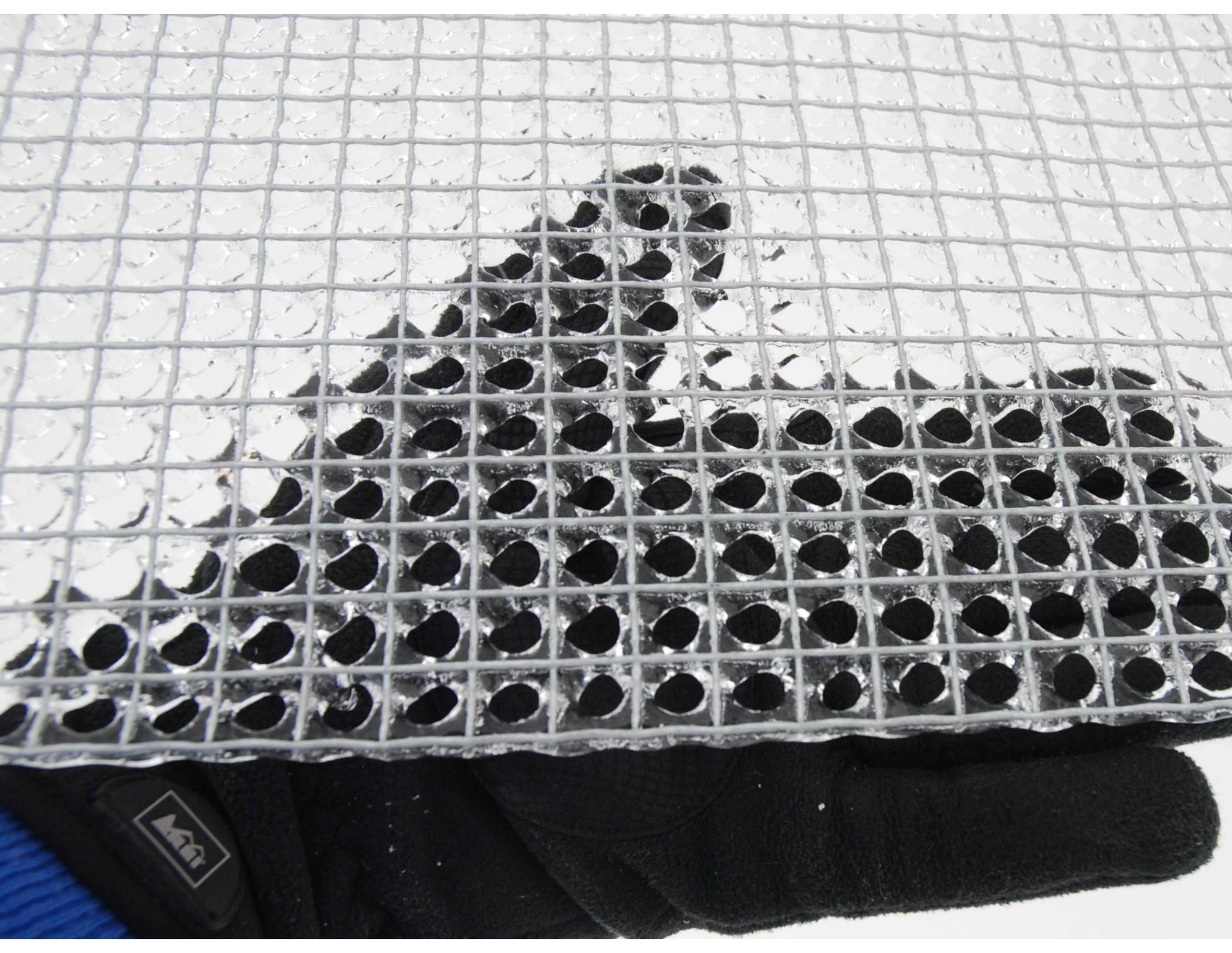


OOTY

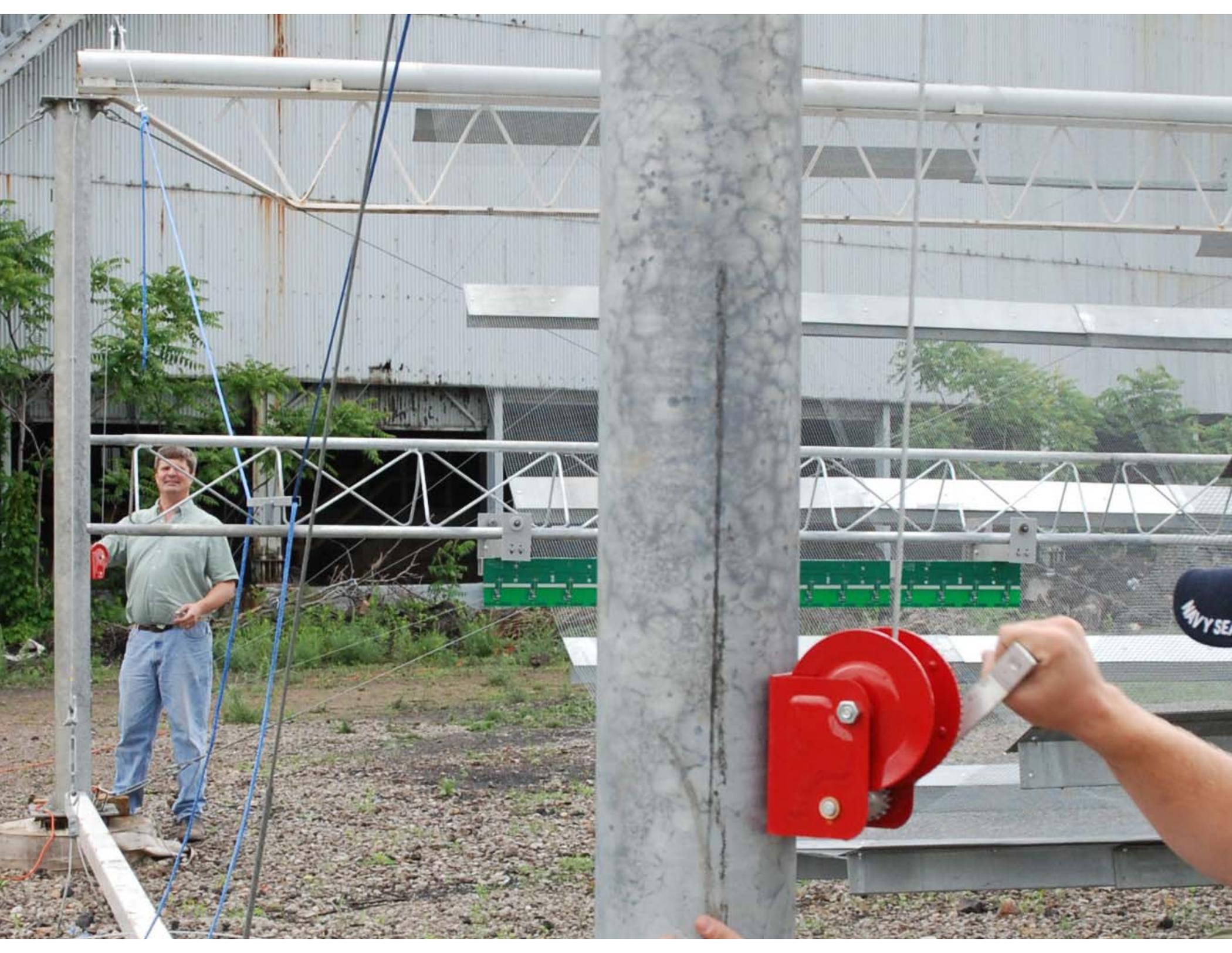


Cambridge

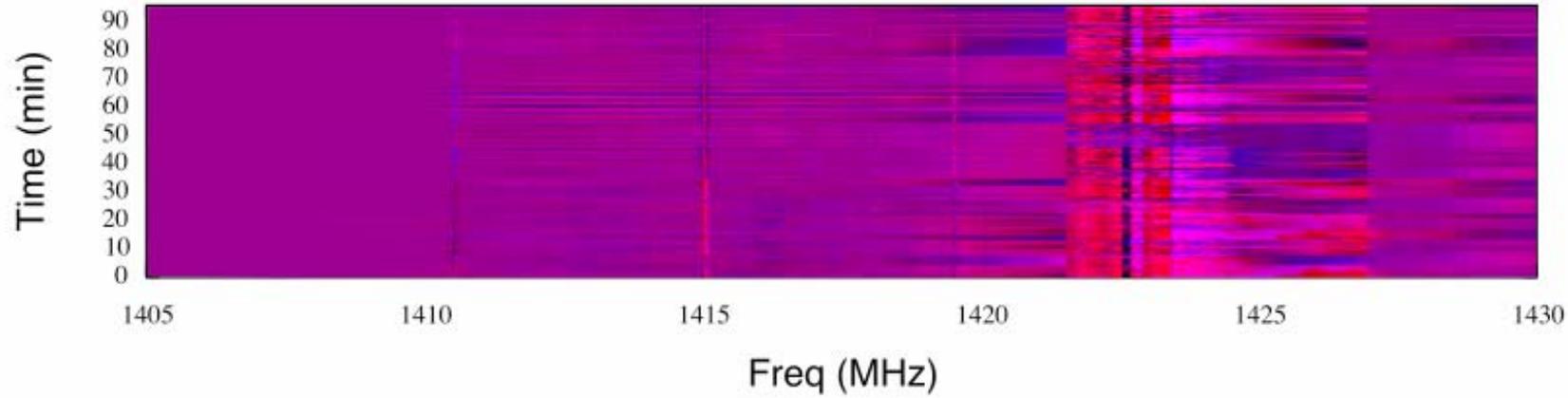




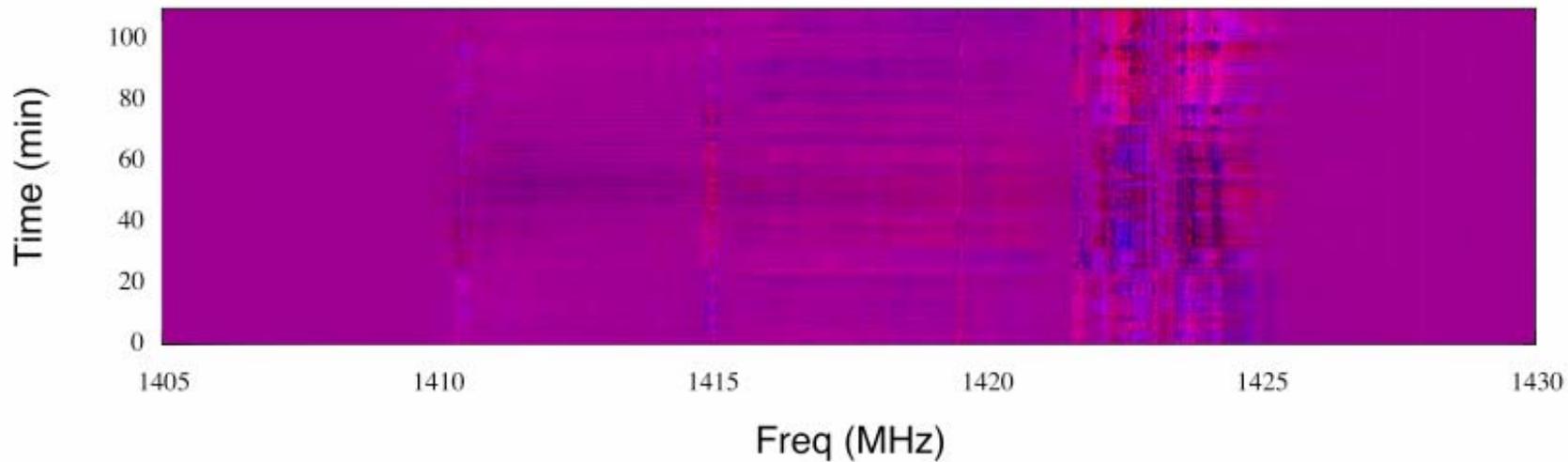




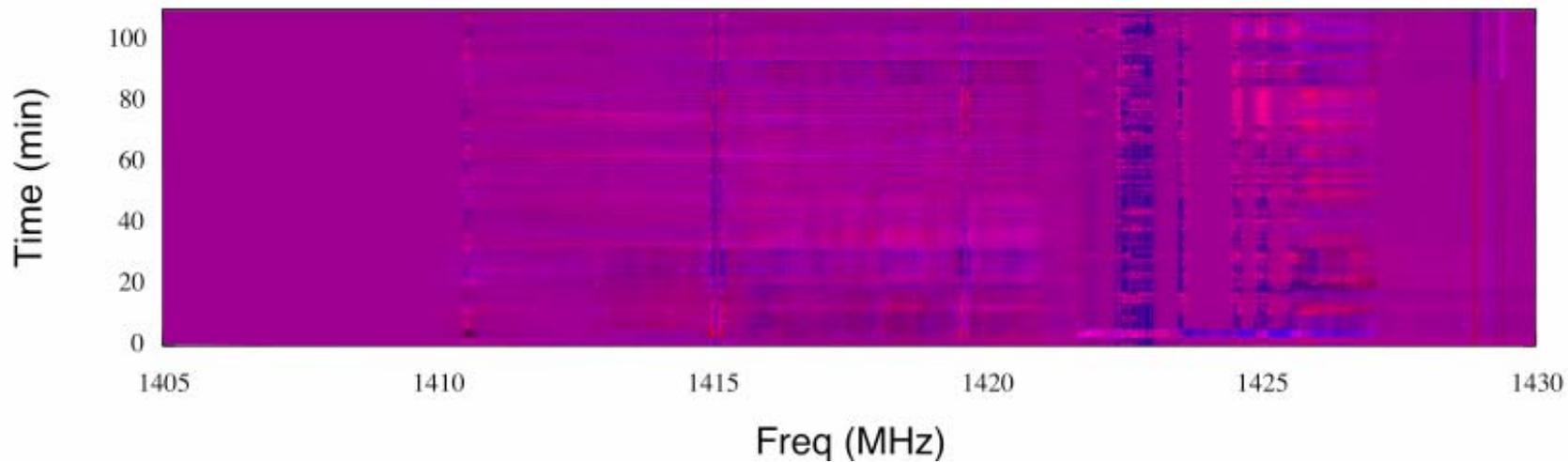




3/26
Started 12:25
Sun Peak at 61 min



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 ~ 0.1
- BAO constraint to dark energy may be available using an intensity mapping prototype.