# Dark Age Telescope

## – λ21cm power spectrum beyond z~15 –

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# DAT Summary

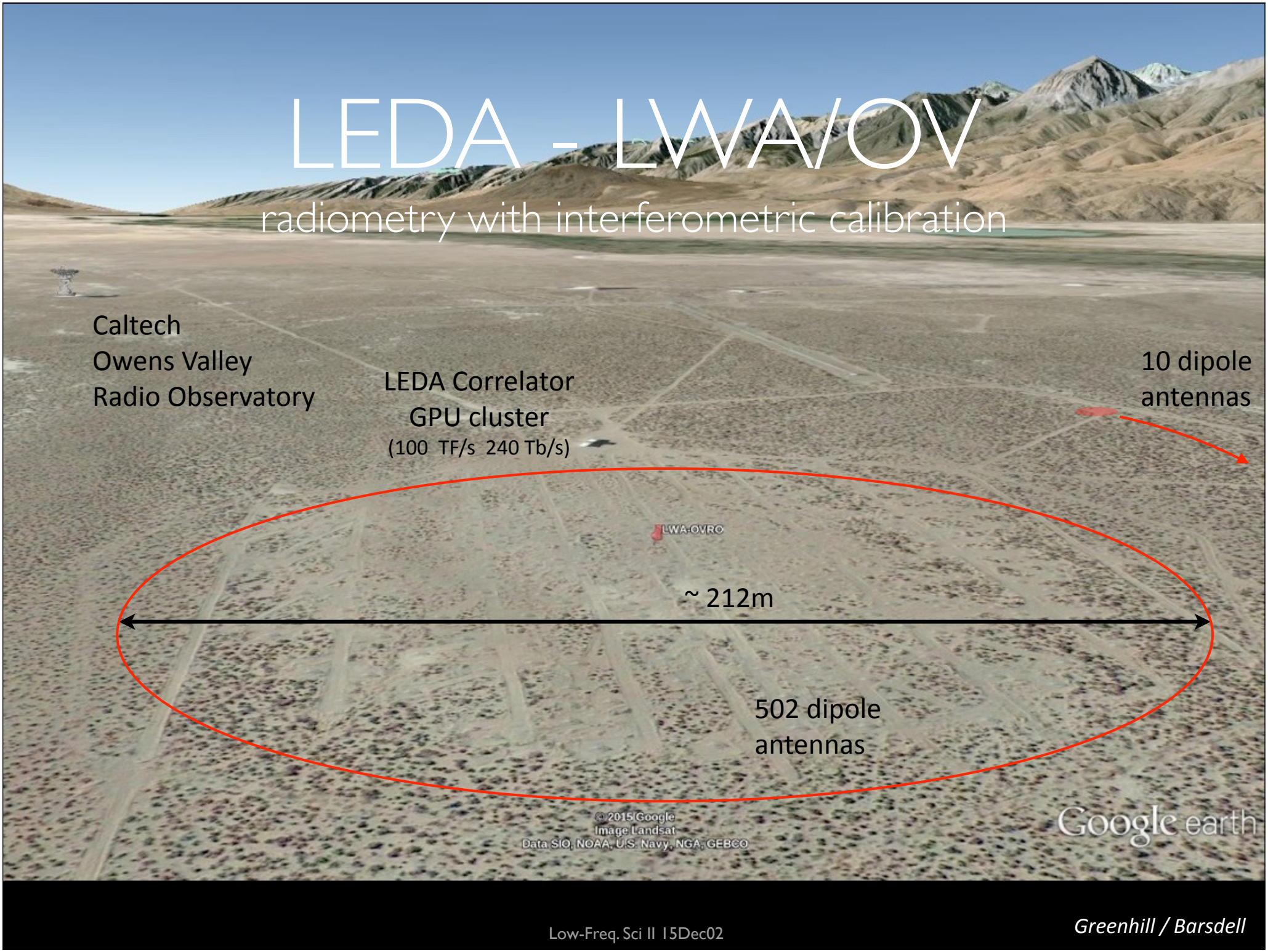
- 21cm cosmology: z >15
- Focus: Dark Age (DA), Cosmic Dawn (CD) – unique physics
  - test theoretical predictions of fundamental processes before the Epoch of Reionization (EOR)
  - quantify initial conditions for interpretation of EOR studies
  - infer conditions backward into the DA
- Instrument: power spectrum array
  - maximally redundant, large-$N_A$ configuration (HERA-like)
  - aperture proximate to a non-redundant, large-$N_A$ compact beamforming array (unique)
    - enables external calibration – leverages long baselines & large-$N_B$
    - enables monitoring of ionosphere and high-fidelity estimation of sky model
- New direction at high redshift
  - orthogonal information w/r to 0-order mode experiments (LEDA, Bighorns, EdgesII)
- Most practical locations
  - Long Wavelength Array(LWA) stations
- LWA1 selected for proposal now in review
  - primary drivers: RFI above 75 MHz, ready infrastructure, extant LEDA systems
- Heritage: **Large Aperture Experiment to Detect the Dark Age – LEDA** (sci/tech)

Price
Sokolowski
Monsalve
talks

# LEDA Radiometry




*Greenhill*





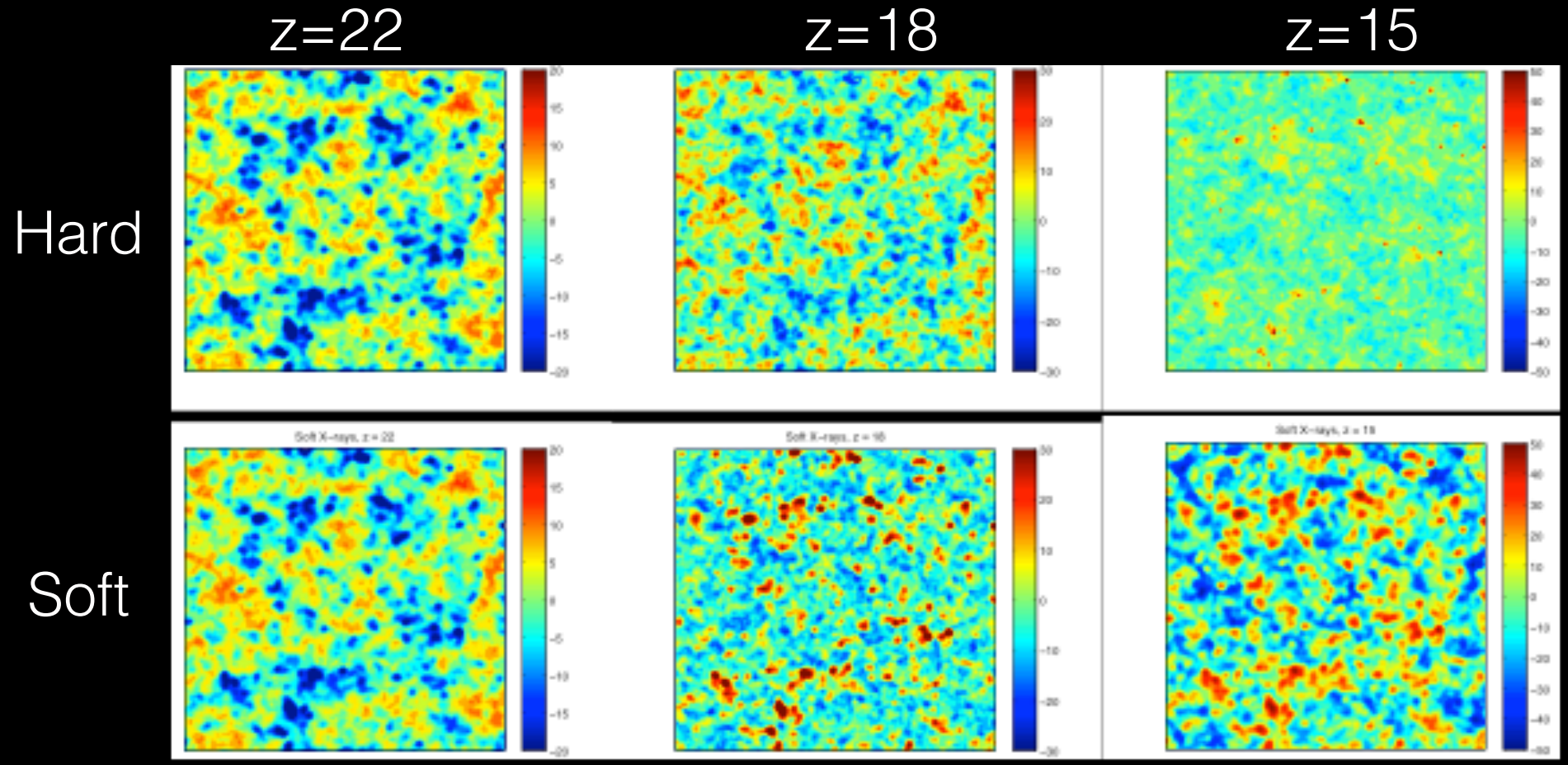

*Greenhill / Barsdell*

# Physics

- DAT will test theories of fundamental processes in the early universe.

| Physics | Process | Effect | Observable |
|---|---|---|---|
| Wouthuysen-Field effect | Ly$\alpha$ coupling of 21cm → $T_s \sim T_k$ | temperature contrasts | ∃ signal @ z>15 |
| Baryon Acoustic Oscillations | Dark matter / baryon drift | light halo star formation eff. | timing/shape of signal |
| Black hole population growth | X-ray energy deposition | hard X-rays heat less efficiently | dilution of signal at "low" z |
| Feedback | Lyman-Werner field Spread of metals | light halo star formation eff. | timing/shape of signal |
| Dark matter annihilation | heating during dark age | warm baryons | light haloes form fewer stars |

# e.g., Structure Depends on Hardness




*courtesy A. Fialkov*

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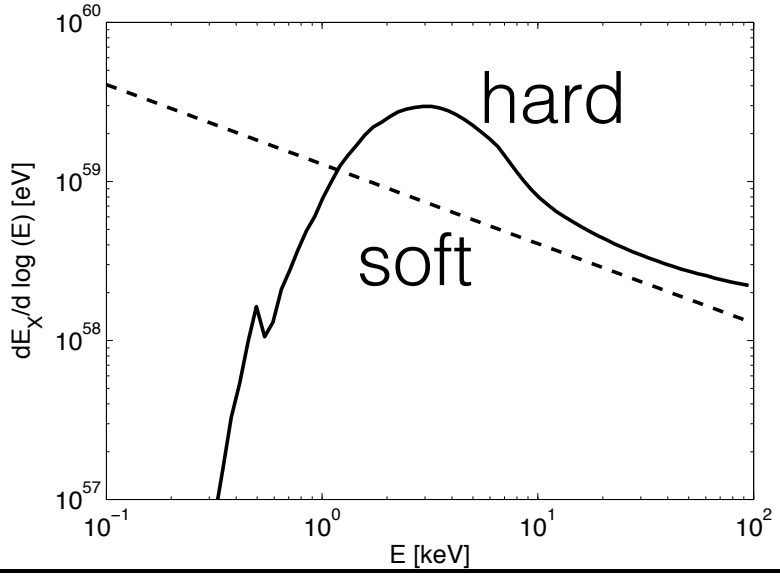
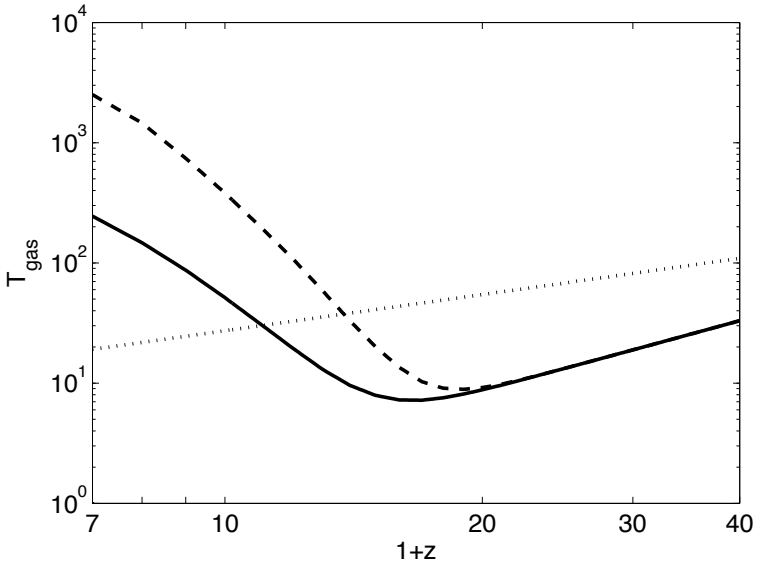
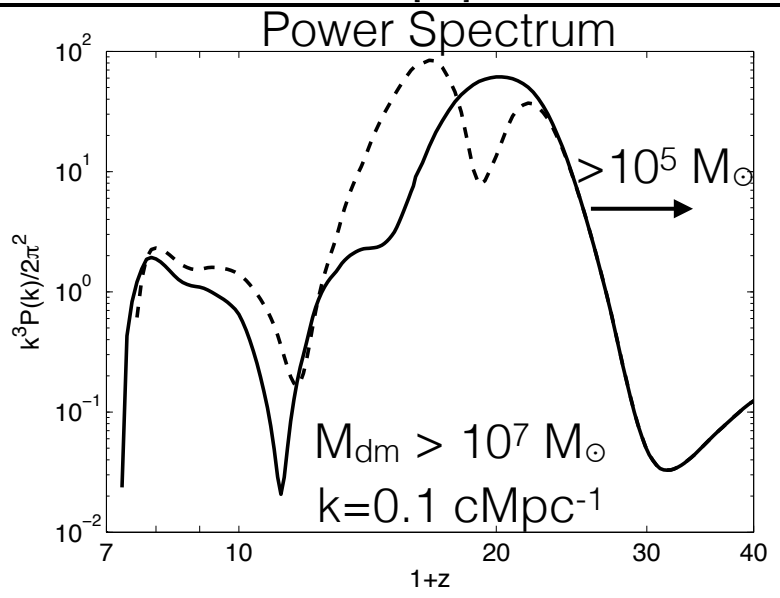
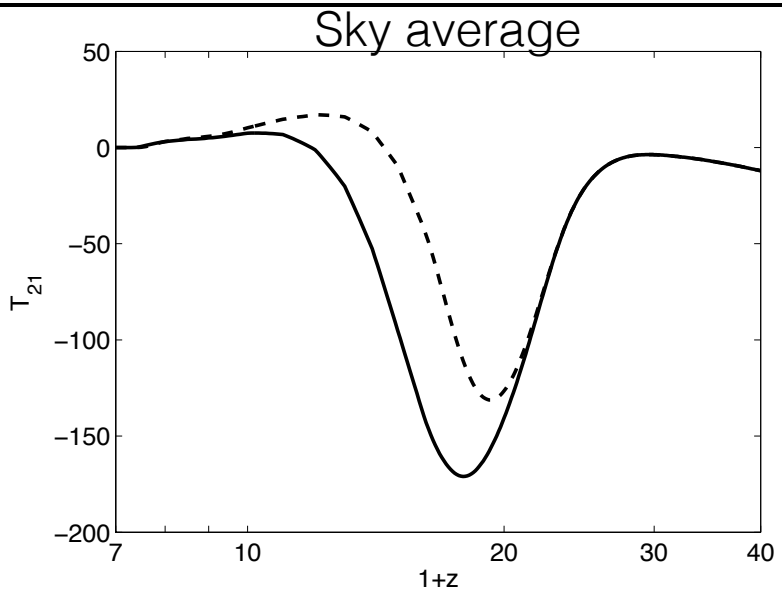
Physical State



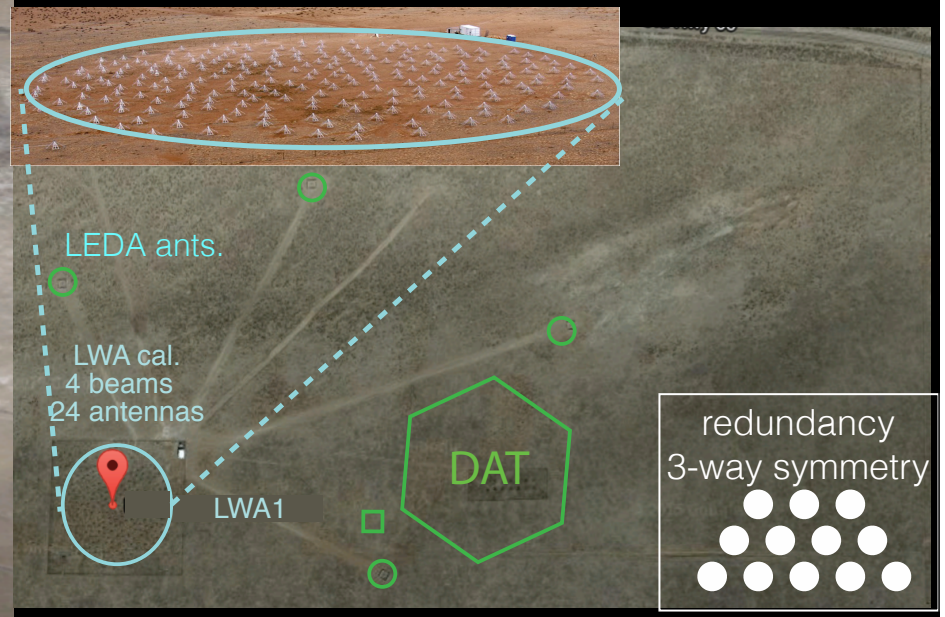

Observable




*courtesy A. Fialkov*

# A Proposed Configuration: NM


DAT hexagon¶ 127 ants. ⌀120m
169 ants. ⌀140m
217 ants. ⌀160m
271 ants. ⌀180m

external cal: 4 LWA1 bms.
plus 24 distributed ants.

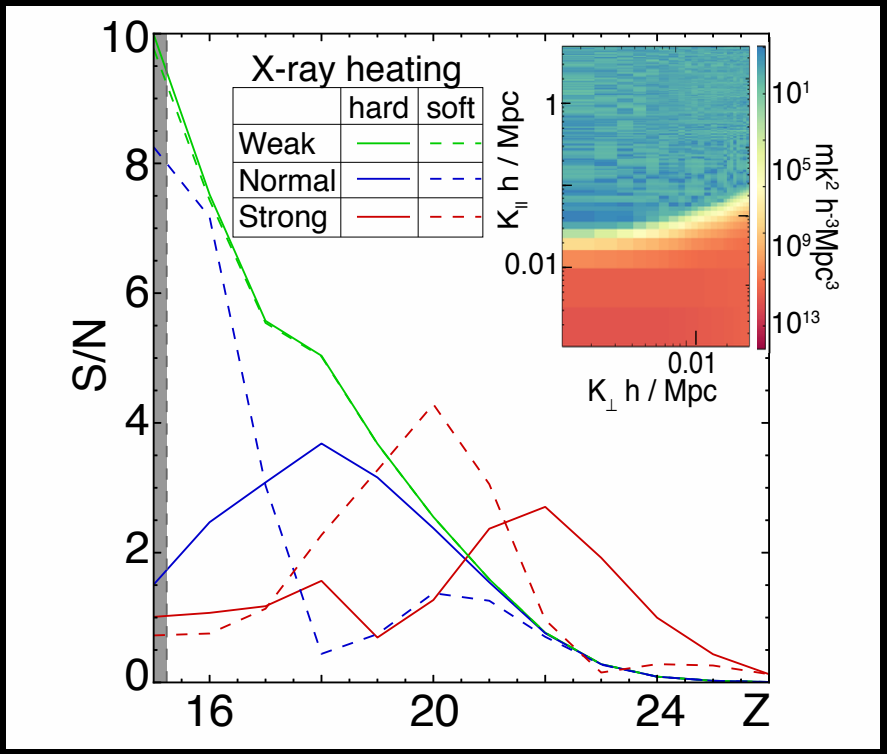
* Siting at LWA1 is under discussion with NRAO
¶ Assumes 2λ spacing at 60 MHz (z=22.7)

# DAT Specifications

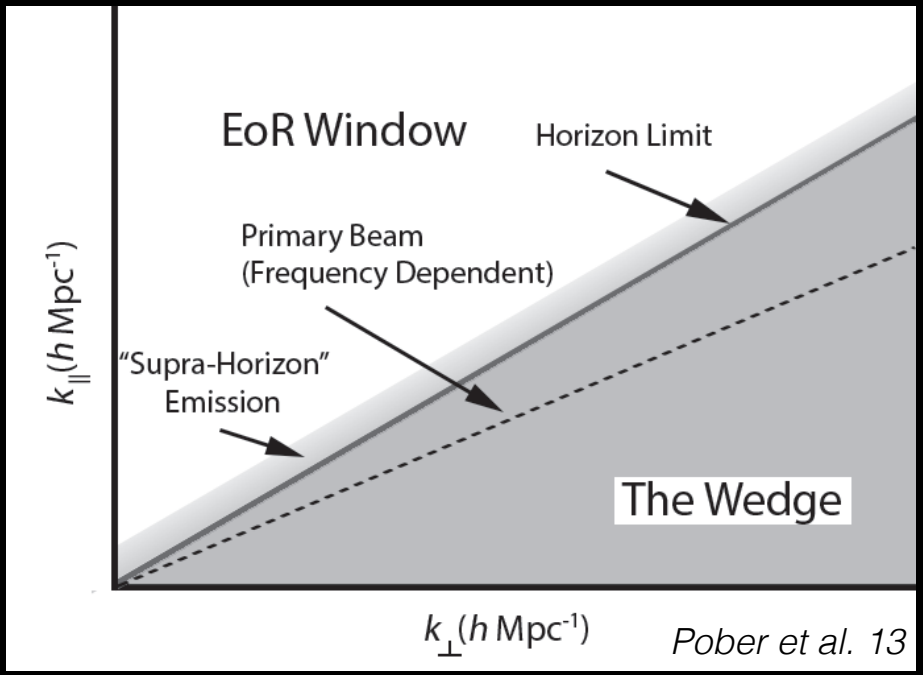
| | |
|---|---|
| Science band<br>Cal. band | 60-87 MHz (15-23)<br>30-87 MHz |
| $N_{ant}$ | 128 - 271 (+24) |
| configuration | hexagonal, redundant<br>+ ext. dense array (LWA1) |
| antenna-type | "regularized, horizon-blind LWA" |
| max. spacing | 120-180m |
| min. spacing | 2λ @ 60 MHz |
| Tsys | 1200 - 3000 K ($T_{rx}$=500 K) |
| Power<br>(via LWA1 infrastructure) | < 7 kW |

Owen talk

# Sensitivity for Minimum-sized DAT



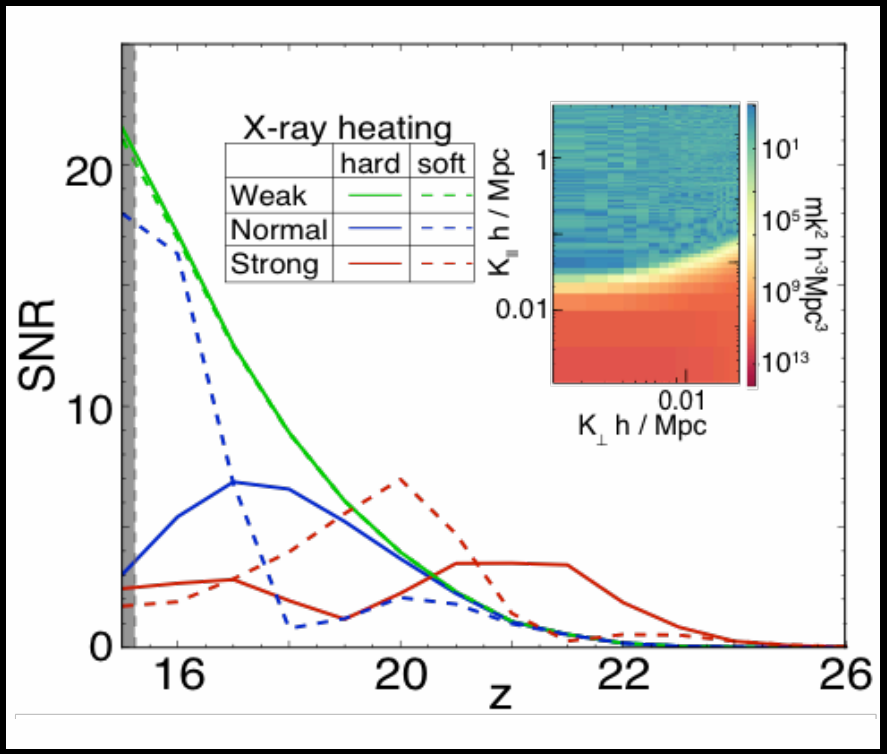

*sim by D. Price using modified 21cmSense*
*inset courtesy C. Trott*




128 ant. and ⌀150m:
3000$^{h}$ (2 yr)
foreground filter: $k_{||} > 0.08$

sensitive to LOS flucts. only
"foreground brick," not wedge
all spacings – efficient aperture

# Sensitivity for LEDA-scale Array

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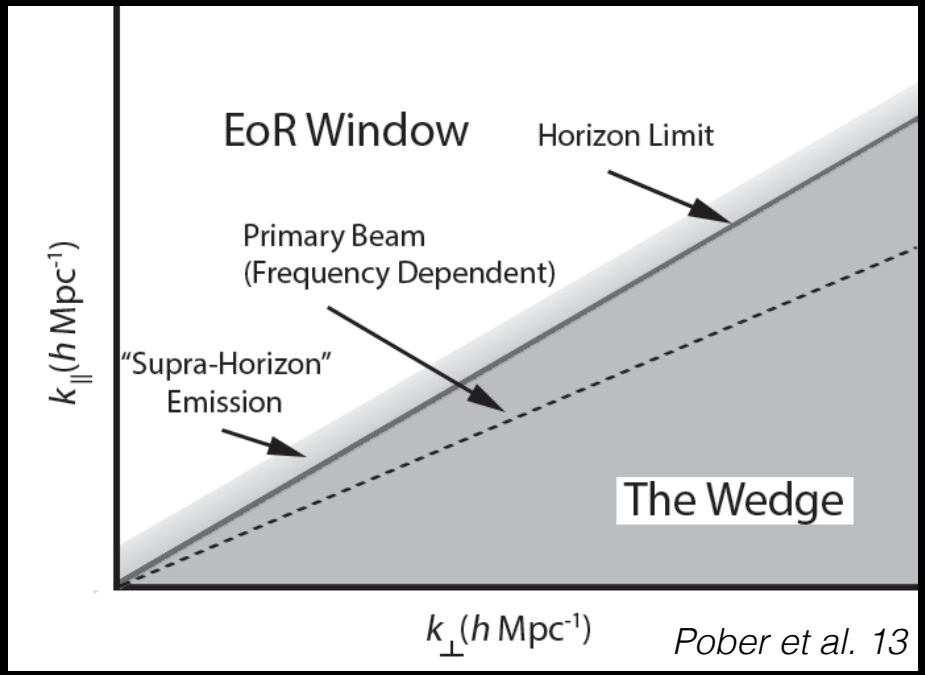


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# Analysis

- Goal: power spectrum in $k_{||}$
- Calibration
  - "correct" bandpass cal. is paramount for foreground mitigation
  - Cuwarp or similar package (Mitchell et al. 08)
  - cross correlate DAT elements with LWA1 beams
    - instantaneous tracking of multiple calibrators
    - estimate dirx'n & frequency-dependent antenna gains
    - monitor ionosphere for quiescent times; apply rubber sheet if needed
  - exploit redundancy (OMNICAL)
- Foreground mitigation
  - peel bright point sources
  - partially peel of diffuse emission model DFT
  - delay filter (e.g., PAPER)

Line
Lenc/Wayth
talks

# Summary

- Proposed Dark Age Telescope
  - z=15-23
  - power spectrum estimation along $k_{||}$
  - orthogonal extension to searches for sky-averaged spectra
    - LEDA, Bighorns, EDGESII
  - joint with a beamforming LWA station
  - transparently scalable w/ $N_A$
    - LEDA FPGA/GPU architecture scales trivially to $N_A$>5000 w/o high cost (not limiting)
- Tests of basic physics, unique to DA and CD
  - Wouthuysen-Field effect
  - Baryon-dark matter drift (BAO)
  - Black hole population growth
  - Spread of metals, LW-feedback
  - Exotic sources of DA heating, e.g., dark matter annihilation

*– end –*