Baseline Redundant Array With LWA-OVRO (BRAWL)

Concept development notes

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1 Introduction

The *Baseline Redundant Array With LWA-OVRO (BRAWL),* is a proposed 127-element interferometric array that will be co-located with the Long Wavelength Array (LWA) at Owens Valley Radio Observatory (OVRO). BRAWL follows the footsteps of the PAPER and HERA telecopes, that exploit redundancy to improve calibration and to target uv-modes of interest. Unlike PAPER and HERA, BRAWL will be targeting the period between the Dark Ages and the Epoch of Reionization, which is referred to as "Cosmic Dawn" or the "Epoch of X-ray heating" (EoX); that is, measurement of the 21-cm emission line at redshifts between 10-40.

This memo details the results of simulations of sensitivity, made with the `21cmsense` package (Pober et. al. [REF]).

2 Code modifications

The `21cmsense` code has been modified reasonably extensively to make it more compatible with the lower frequency range. Some noteworthy changes:

- Code now uses a simulated LWA antenna beam response to compute Ω', the 'effective beam solid angle' and the 'dish size in λ' parameters used in the code for sensitivity estimates and gridding.
- The two main script routines were converted into functions, so that they can be called/imported in other scripts so as to run loops over parameter spaces.
- Added some plotting functionality for quick-looks at UV coverage, models, and antennas
- Modified code to accept 2D power spectra as an input, from which 1D slices can be generated.
- Added 'Trott' foreground model (simple scalar $k_{||}$value).

Additionally, the code no longer does frequency scaling, as the fractional change from 30-88 MHz is large. This means for every redshift of interest, UV coverage is recalculated, adding extra compute time to the sensitivity estimate.

3 Input models and parameters

Power spectra model A. Fialkov has run some initial simulations for the expected 21-cm signal over $7 < z < 40$, for a range of k values between 0.0-1.6 (Figure 1), which are used as an input for `21cmsense`. Note that there is noise at lower k due to cosmic variance in the data cube used.

Antenna array For antenna placement, we are using a hexagonal-packed 127-element array with 10-m spacing (Figure 2). While for some k modes closer spacing would be preferable, mutual coupling between antenna elements is of concern. UV coverage is shown in (Figure 3), with the value of each cell representing the number of baselines sampling that (u,v) mode.

Antenna parameters We assume the use of an LWA antenna, and use simulations from NEC4 of the beam pattern. Aperture efficiency is not currently considered.

System temperature The system temperature is given by

$$T_{sys} = T_{rx} + T_{sky}(\nu),$$

where T_{rx} is the receiver temperature, and is set to 500 K, and using a sky model

$$T_{sky} = T_0 \lambda^{2.55}$$

with $T_0 = 60$. The sky model thus gives a temperature of 1369 K at 88 MHz, increasing to 21288 K at 30 MHz. Using a more realistic sky model (i.e. based upon LEDA observations) would be advantageous for future simulations.

Foreground model We use a foreground model based off simulations by C. Trott (Figure 4), with $k_{\|} = 0.1$ Mpc^{-1} . Of note is that these predict no 'wedge', rather a scalar horizon (aka 'brick') on $k_{\|}$ (presumably the wedge is off at higher $k_{\perp}$ than those measured).

Observation parameters Default parameters are used elsewhere in the code. This corresponds to 180 days of 6-hour drift-scan observations. A cosmological bandwidth of 8 MHz (redshift range that is co-evaluated) is used. Both conservative and optimistic models for the foreround wedge are presented.

4 Results

Using `21cmsense`, we computed the expected signal-to-noise ratio for the A. Fialkov PS model, under 'Trott-limited' and complete foreground removal models.

Simulations suggest that a $> 5\sigma$ detection of the PS can be made over the redshift range $16 \leq z \leq 18$ for several models (Figure 5), assuming all modes above the 0.1 Mpc^{-1} limit can be used. Perfect foreground removal results in $> 5\sigma$ detections for all models, but this may not be plausible.

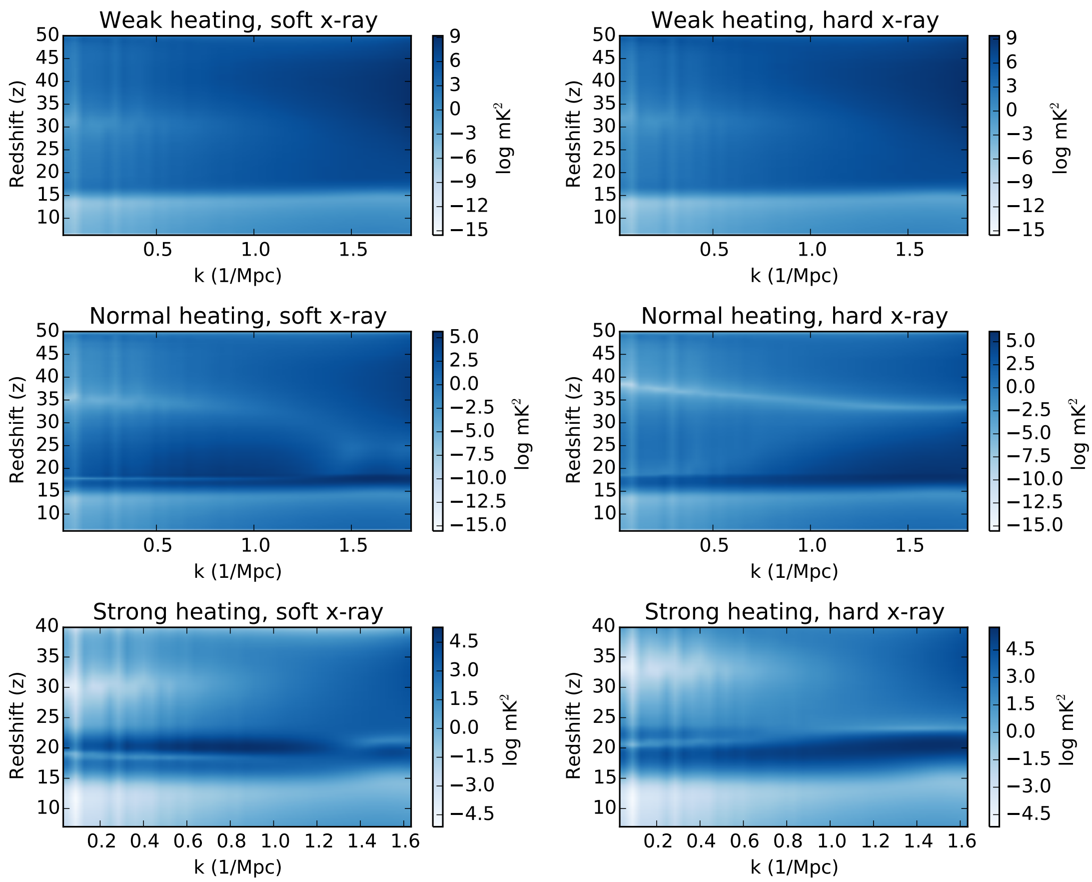


Figure 1: Simulated 21-cm power spectrum over the Dark Ages and Cosmic Dawn, for a variety of heating and x-ray luminosity scenarios..

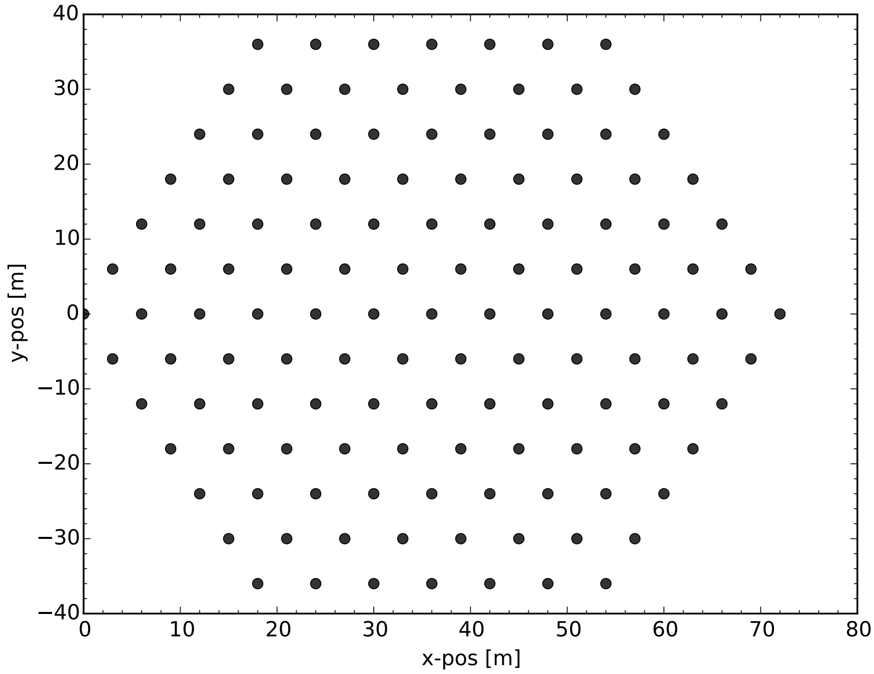


Figure 2: Antenna positions for the proposed BRAWL instrument.

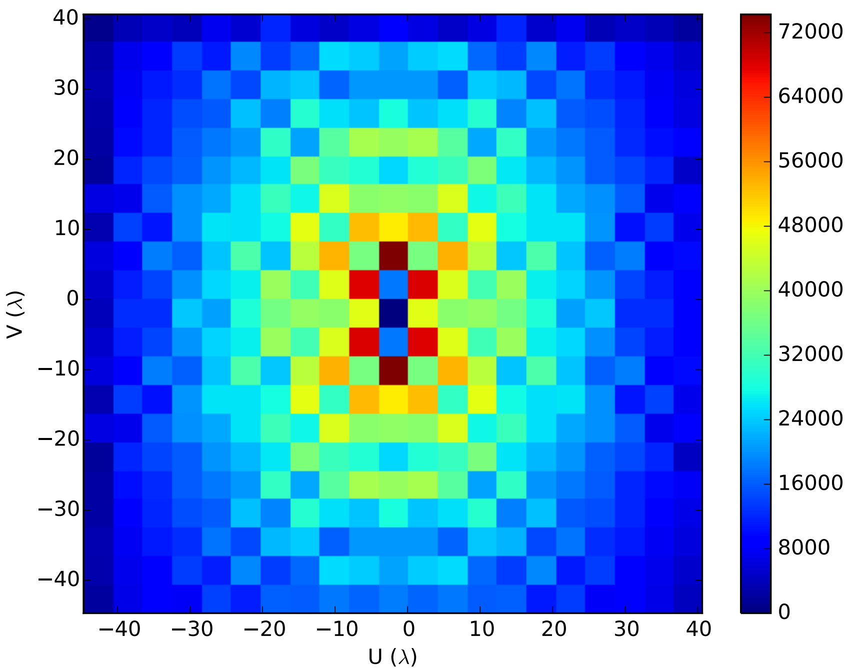


Figure 3: UV coverage of BRAWL array, as computed at 50 MHz..

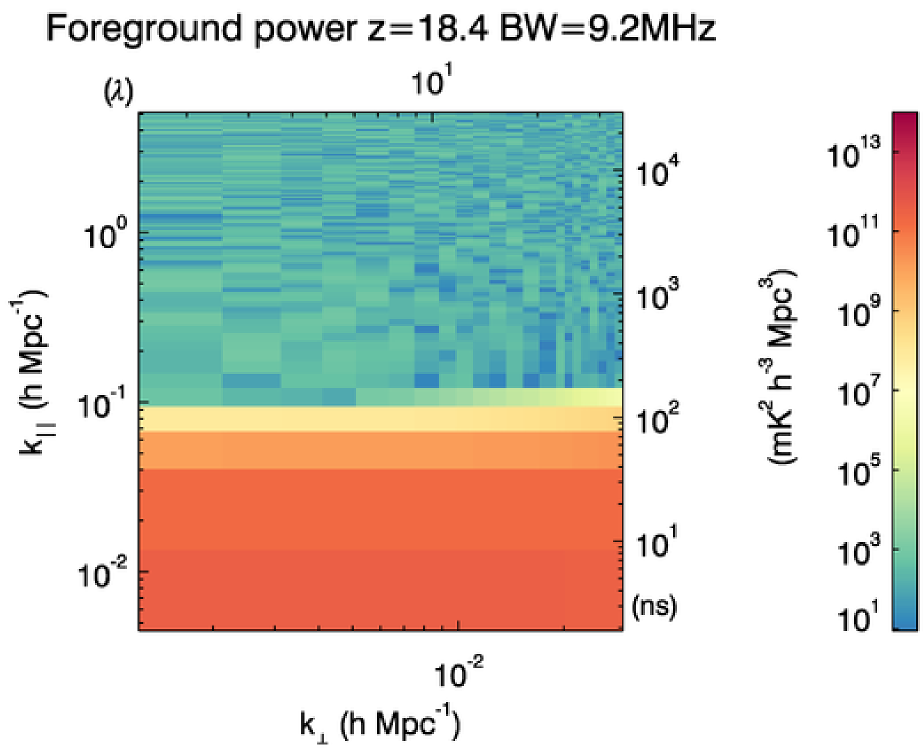
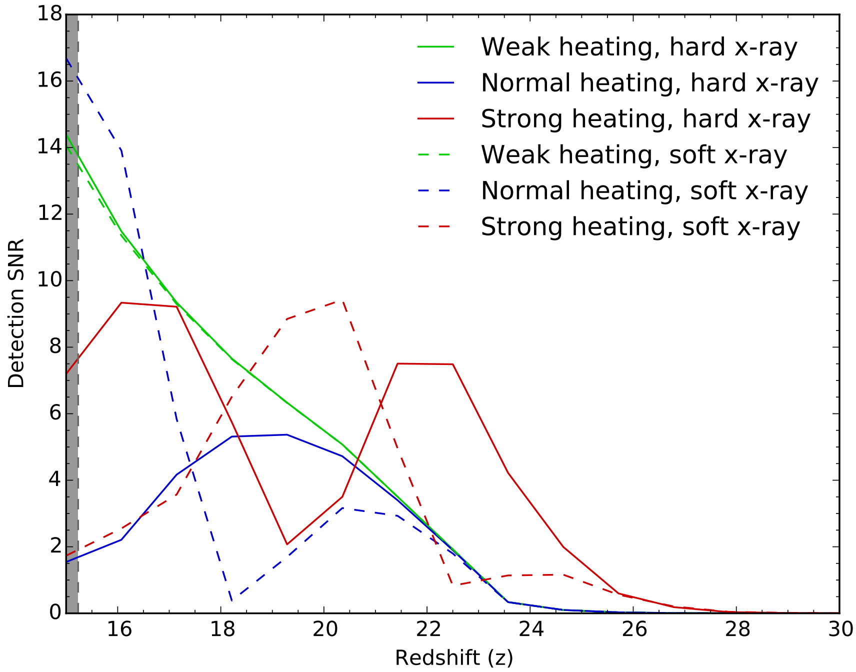
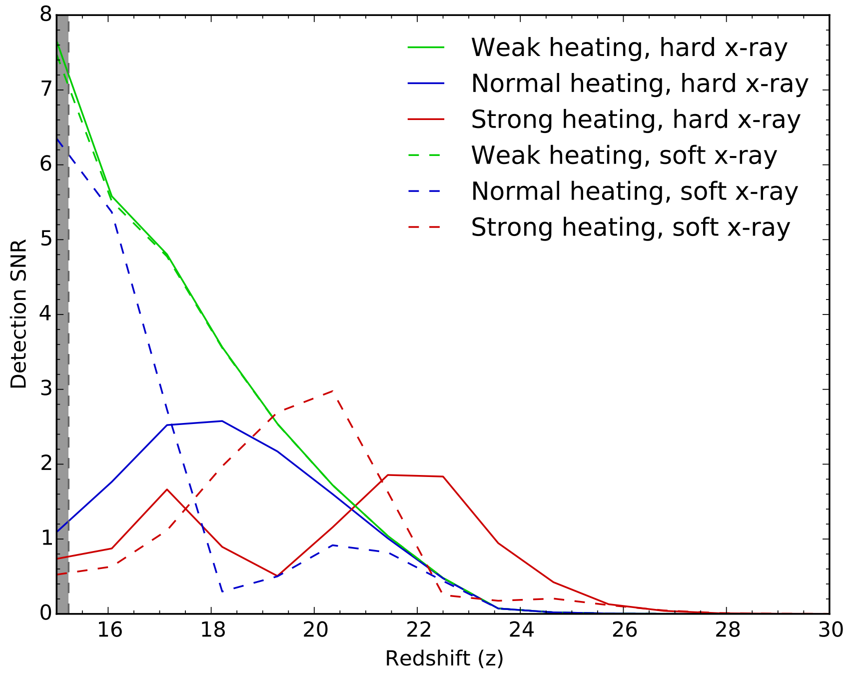


Figure 4: Foreground model, from C. Trott. Clearly this is not 'wedge-like', but 'brick-like'.



(a) No foregrounds



(b) Trott foreground model, i.e. $k_{\|} = 0.1$ Mpc^{-1} .

Figure 5: Simulated signal-to-noise ratio (SNR) for power spectra as a function of redshift. The shaded area corresponds to the FM radio band, over which RFI is a significant impediment to astronomical observations.