HERA-19
Commissioning

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Abstract

The Hydrogen Epoch of Reionization Array (HERA) is a low frequency (100-200 MHz), 350-dish radio interferometer currently under construction at the SKA site in the Karoo. Its main goal is to observe the evolution of the 21-cm line emitted by the intergalactic medium in the $6 < z < 12$ range, therefore providing a complete characterization of cosmic reionization. The first 19 dishes were deployed at the end of 2015. Here I present the results that we obtained after reducing three Julian days (2457545, 2457555 and 2457661) worth of HERA-19 snapshots using our own custom built commissioning pipeline. Each of the three Julian days that we processed contained 72 ten minute snapshots.

Pipeline

The basic HERA-19 pipeline that was implemented is shown in the flow diagram below. We mainly concentrate on how the calibration sub-blocks were implemented in this poster.

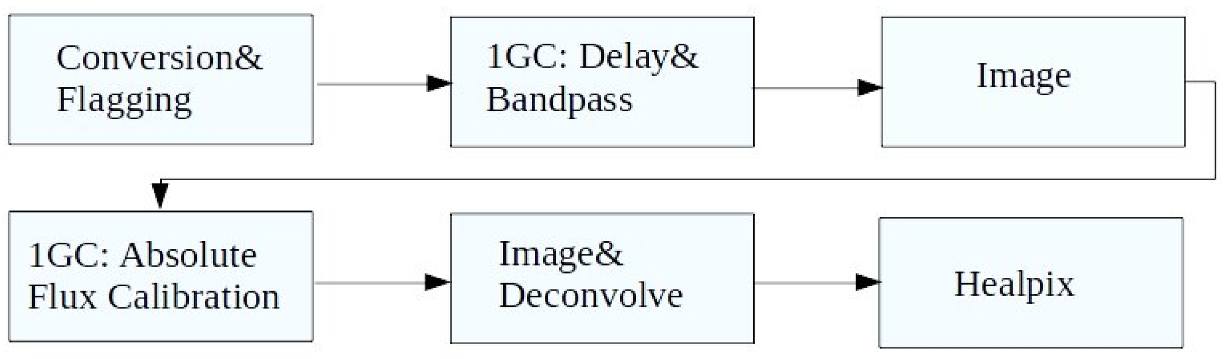
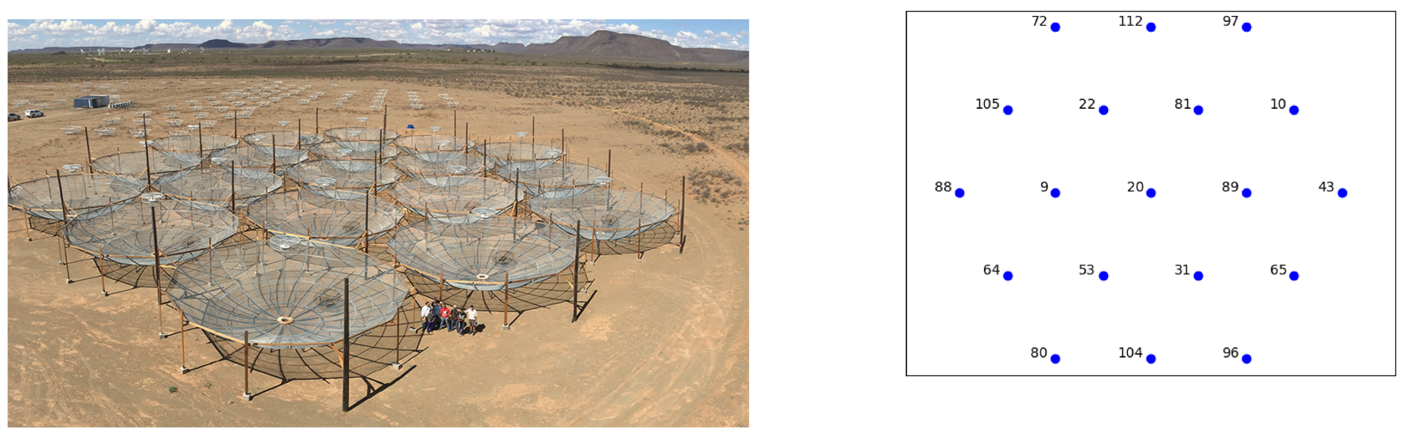


Figure 1: The custom built HERA-19 Pipeline. `https://github.com/Trienko/heracommissioning`.

An image of the HERA-19 array is shown below.



(a) HERA-19 Image　　**(b)** HERA-19 Layout

Figure 2: HERA-19.

Calibration

Our pipeline only includes a first generation calibration (1GC) step (i.e. we make use of calibrator sources). The calibration procedure we used consisted of a two stage process.

Delay and Bandpass Calibration

1. Find the snapshot in which the Galactic center is closest to transit.
2. Do a delay and bandpass calibration assuming a 1Jy point source model for the Galactic center.
3. Apply gain solutions to all other snapshots.

The computed delays seem to be quite stable as, even after ten days, there is almost no change in the delays. After ~100 days we see a bit more deviation, although not as much as one would expect.

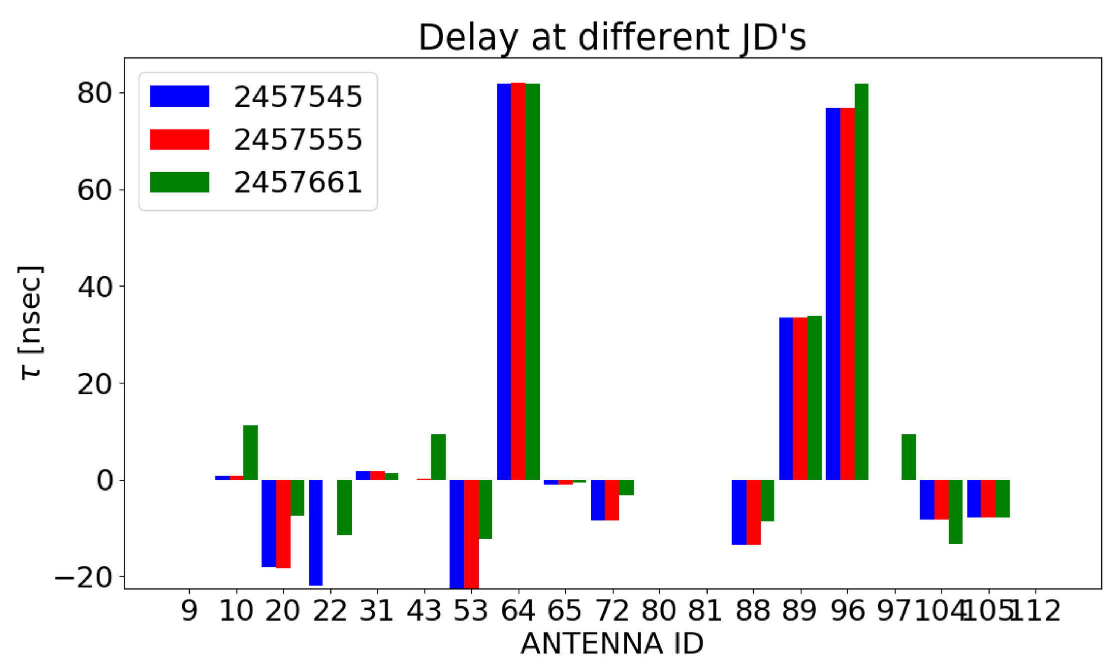
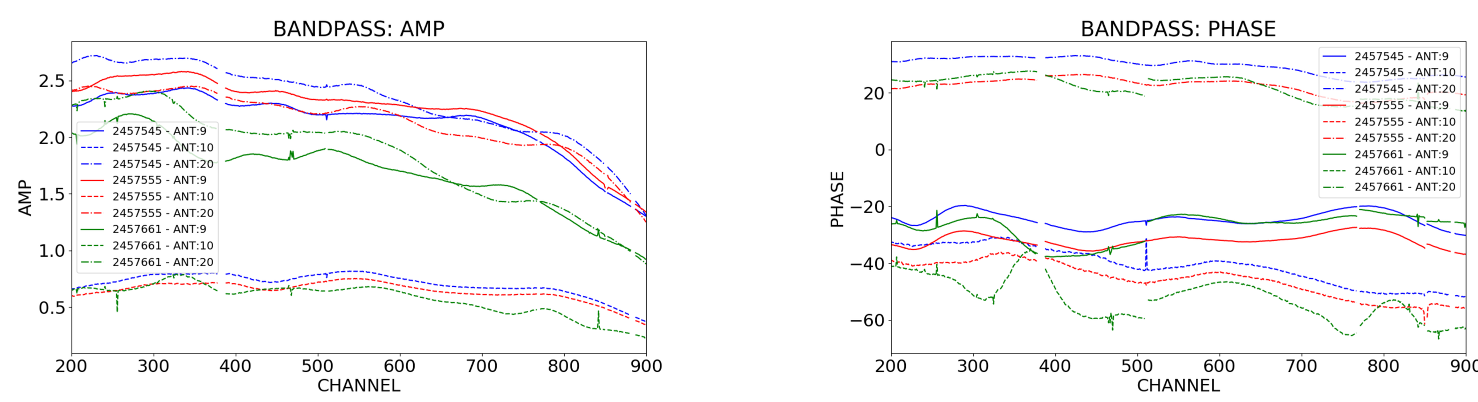


Figure 3: The computed delays.

The bandpass gain solutions are depicted below for a subset of antennas. The phases are almost flat as the phase slope was removed by the delay calibration step. Again the bandpass gains also seem to be quite stable over time.



(a) Bandpass: Amplitude　　**(b)** Bandpass: Phase

Figure 4: Bandpass gain solutions.

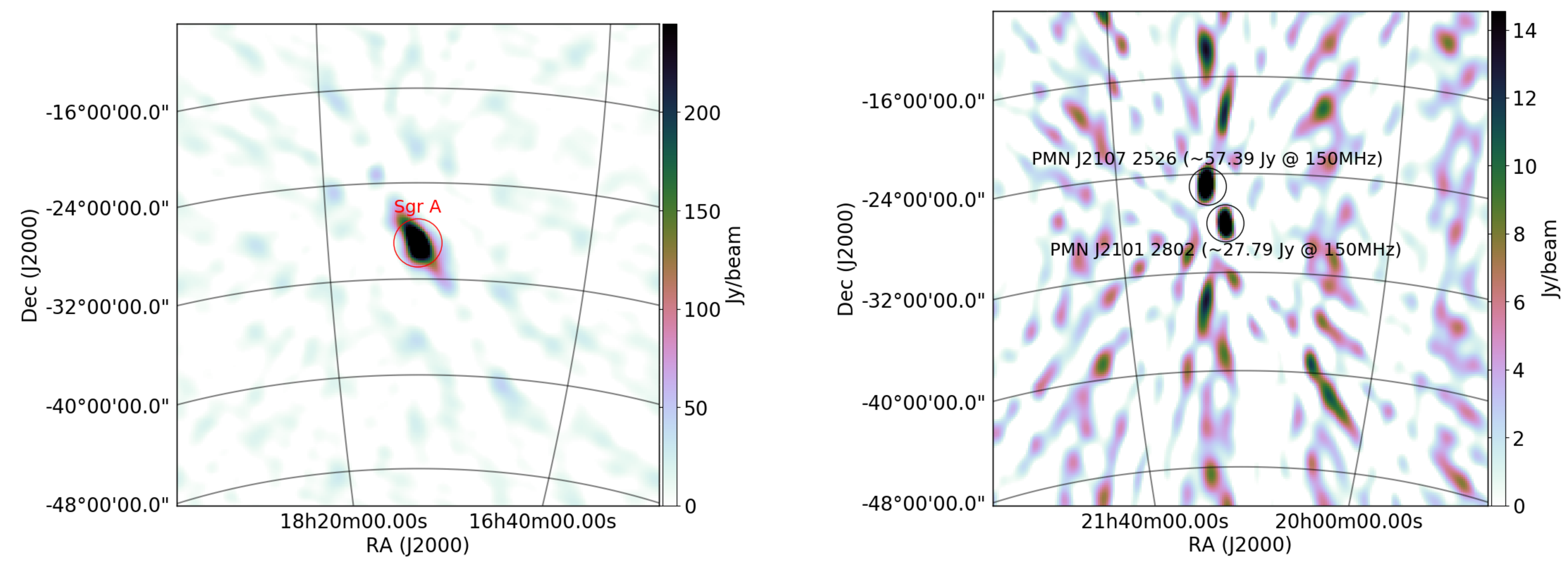
Absolute Flux Calibration

1. Find the snapshots containing the two flux calibrators (PMN J2101 2802 and PMN J2107 2526).
2. Use Eq. (1) to obtain the correct scale factor.
3. Apply scale factor to all other snapshots.

The absolute flux calibration procedure we used is based on the following equation:

$$C = \frac{\sum_{kt}(B_{kt}^{\nu})^2 \sum_k M_k^{\nu}}{\sum_{kt} B_{kt}^{\nu} S_{kt}^{\nu}}, \tag{1}$$

where B_{kt}^{ν} is the attenuation factor source k experiences due to the primary beam at time t and frequency ν, S_{kt}^{ν} is the measured uncalibrated apparent flux (not connected to the correct flux scale) of source k at time t and frequency ν and M_k^{ν} represents the intrinsic flux density of source k at frequency ν. Calibrated images of the delay and bandpass calibrator (Galactic Center) and the absolute flux calibrators (PMN J2101 2802 and PMN J2107 2526) is displayed in the following two figures.



(a) Delay and Bandpass Calibrator　　**(b)** Absolute Flux Calibrators

Figure 5: Calibrators @ 150 MHz.

HEALPIX

The calibrated snapshots are projected and stitched together (using squared beam weighting) onto a HEALPIX map during the final step of the pipeline. The output HEALPIX map obtained by combining three entire Julian days worth or snapshots is seen below. The acronyms GC and ABS (visible in the figure below) respectively refer to the Galactic center and absolute flux calibrator fields

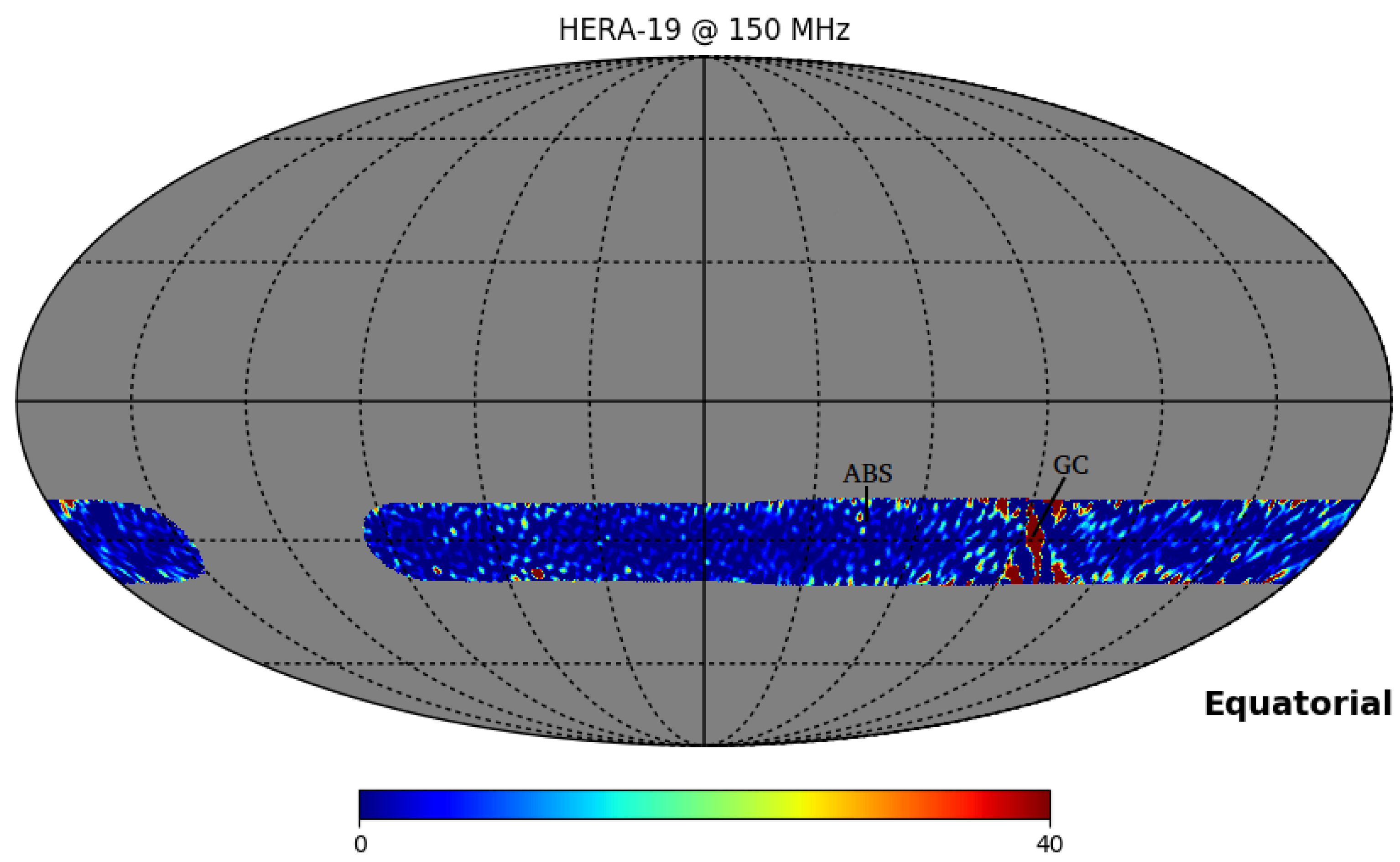


Figure 6: HERA-19 @ 150 MHz (2457545, 2457555 and 2457661). The units of the colorbar is Jy.

References

[1] G Bernardi, LJ Greenhill, Daniel A Mitchell, SM Ord, BJ Hazelton, BM Gaensler, A de Oliveira-Costa, MF Morales, N Udaya Shankar, R Subrahmanyan, et al. A 189 mhz, 2400 deg2 polarization survey with the murchison widefield array 32-element prototype. *The Astrophysical Journal*, 771(2):105, 2013.

[2] David R DeBoer. The hydrogen epoch of reionization array (hera). In *Electromagnetics in Advanced Applications (ICEAA), 2016 International Conference on*, pages 525–528. IEEE, 2016.