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Comparing Redundant and Sky Model Based Interferometric Calibration

A First Look with Phase II of the MWA

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Redundant Calibration (omnical)

logarithmic method[1]

We let the gain to be in the form of $g = e^{\eta + i\phi}$ with η to be the amplitude factor and ϕ to be the phase.

$$v_{ij} = g_i^* g_j y_{ij} + n_{ij} = g_i^* g_j y_{ij}(1 + \frac{n_{ij}}{g_i^* g_j y_{ij}}) \tag{1}$$

$$ln(v_{ij}) = \eta_i + \eta_j + i(\phi_j - \phi_i) + ln(y_{ij}) + \omega_{ij} \tag{2}$$

We separate the real and imaginary parts of eq(2):

$$ln(|v_{ij}|) = \eta_i + \eta_j + ln(|y_{ij}|) + Re(\omega_{ij}) \tag{3}$$

$$arg(v_{ij}) = \phi_j - \phi_i + arg(y_{ij}) + Im(\omega_{ij}) \tag{4}$$

linearized method[1]

We use Taylor expansion on the gains about our fiducial guess η^0,ϕ^0:

$$\begin{aligned} g =& e^{\eta+i\phi} \\ =& g^0 + \frac{\partial g}{\partial \eta}|_{\eta^0,\phi^0}(\eta-\eta^0) + i\frac{\partial g}{\partial \phi}|_{\eta^0,\phi^0}(\phi-\phi^0) + \dots \\ \approx& e^{\eta^0+i\phi^0}[1+(\eta-\eta^0)+i(\phi-\phi^0)] \end{aligned} \tag{5}$$

We plug (5) into visibility calculations, find the deviation of visibility measurements from our fiducial guess:

$$\begin{aligned} \delta_{ij} =& v_{ij} - v_{ij}^0 \\ \approx& e^{\eta_i^0 - i\phi_i^0} e^{\eta_j^0 + i\phi_j^0}[\Delta y_{ij} + y_{ij}^0(\Delta\eta_i + \Delta\eta_j - i\Delta\phi_i + i\Delta\phi_j)] \end{aligned} \tag{6}$$

where $\Delta\eta = \eta - \eta^0$, $\Delta\phi = \phi - \phi^0$, $\Delta y_{ij} = y_{ij} - y_{ij}^0$.

Omnical on MWA PhaseII Data

MWA PhaseII Tiles

Figure 1: MWA PhaseII Tiles

MWA PhaseII Tiles

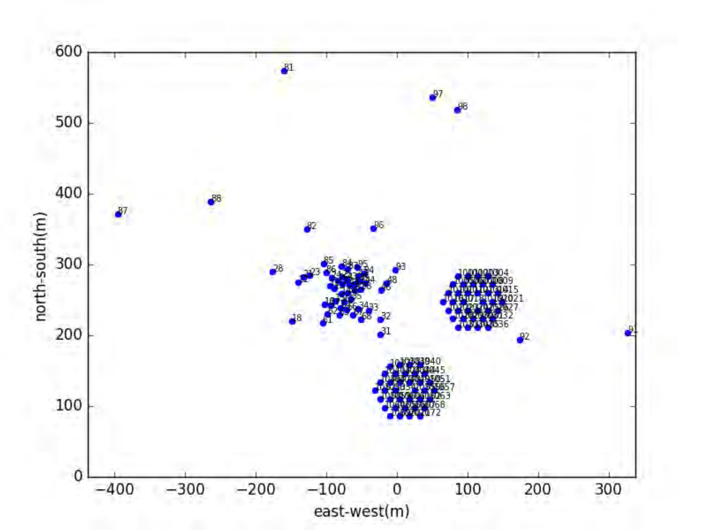


Figure 2: MWA PhaseII configuration

ORBCOMM Observations

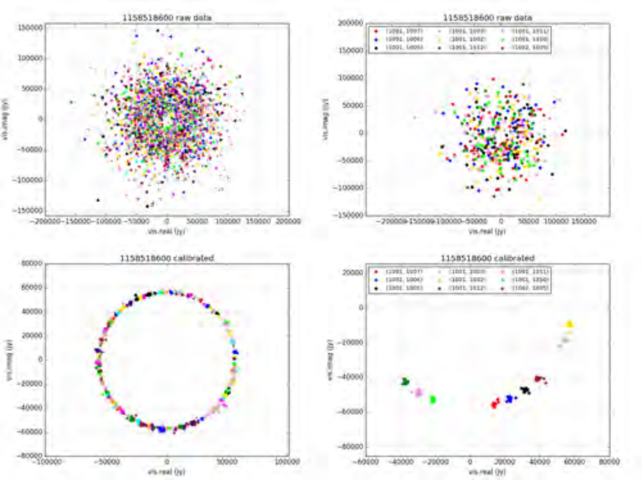


Figure 3: Complex visibilities plots of ORBCOMM observation at 137.1MHz, 4 sec integration. Each unique combination of color and shape represents visibility measurements from a unique baseline type

EoR0 Observations

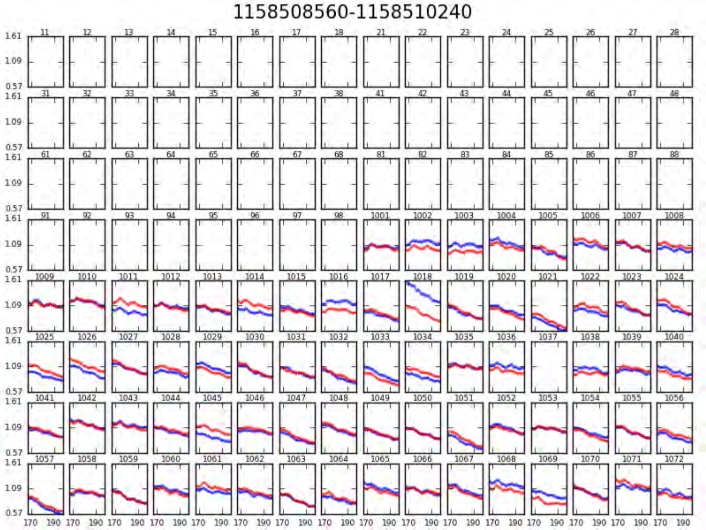


Figure 4: Amplitude solution from omnical on EoR0 data

EoR0 Observations

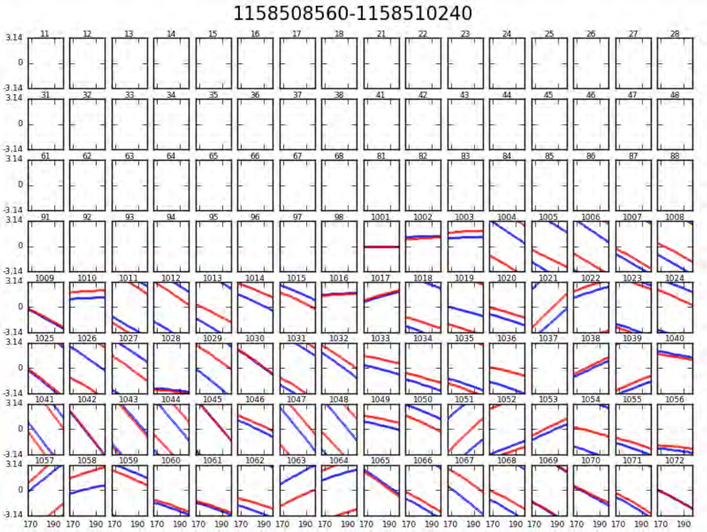


Figure 5: Phase solution from omnical on EoR0 data

FHD sky model calibration on MWA PhaseII Data

EoR0 Observations

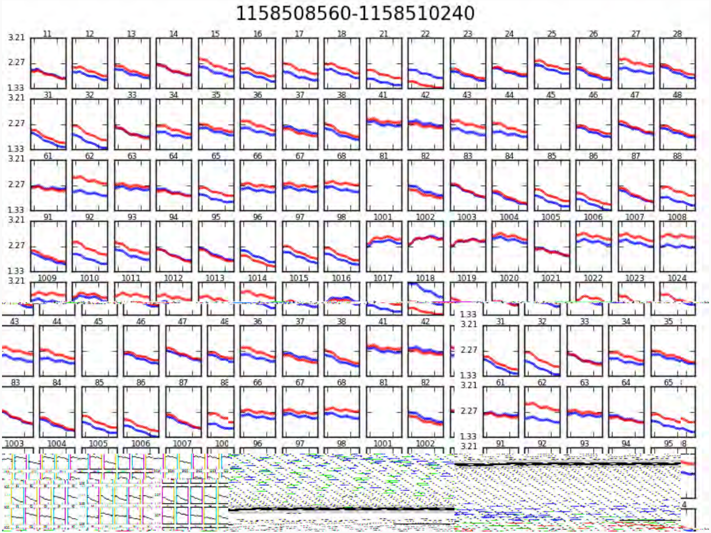


Figure 6: Amplitude solution from FHD on EoR0 data

EoR0 Observations

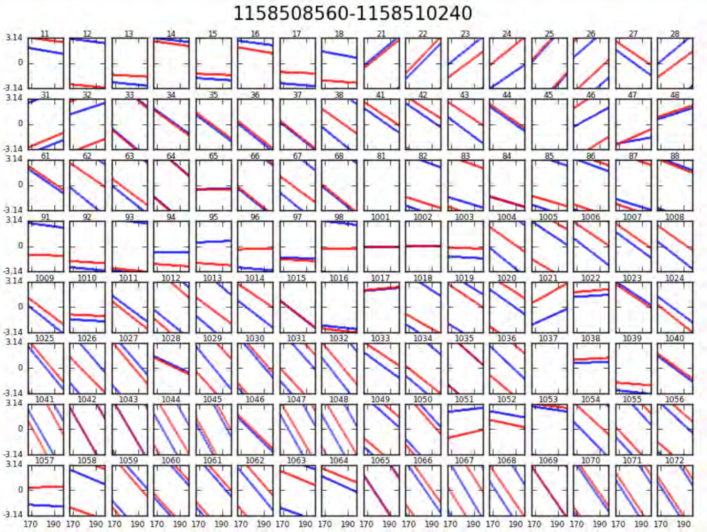


Figure 7: Phase solution from FHD on EoR0 data

EoR0 Observations

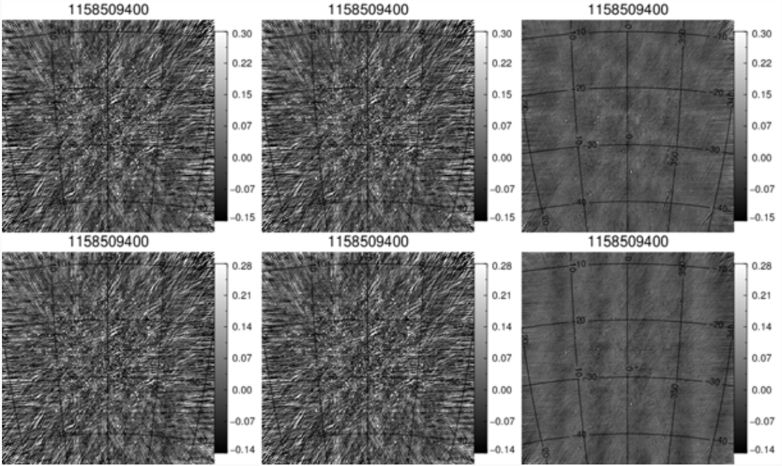


Figure 8: Columns from left to right: Dirty image, Model image, and Residual; Upper row: polarization xx; Bottom row: polarization yy

EoR0 Observations

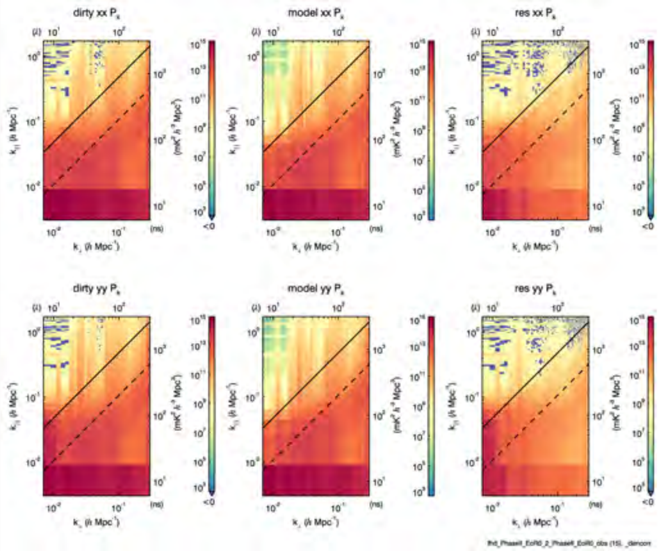
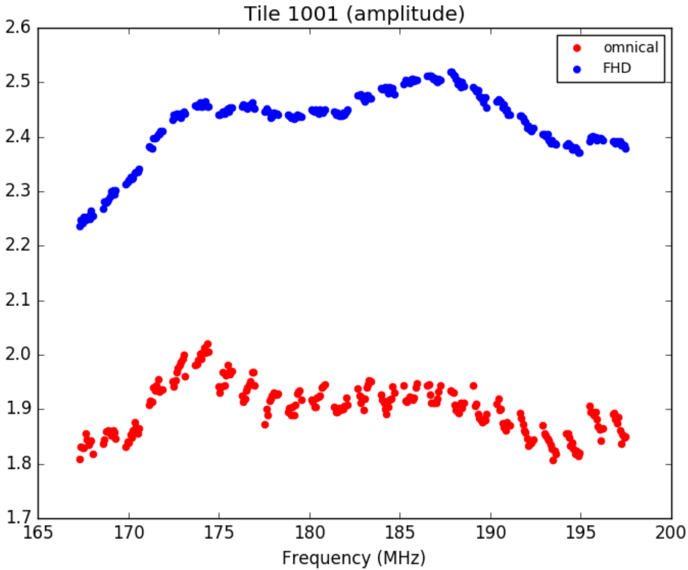


Figure 9: Power Spectrum after FHD calibration.

FHD vs omnical



Combining omnical and FHD together?

Visbility clustering

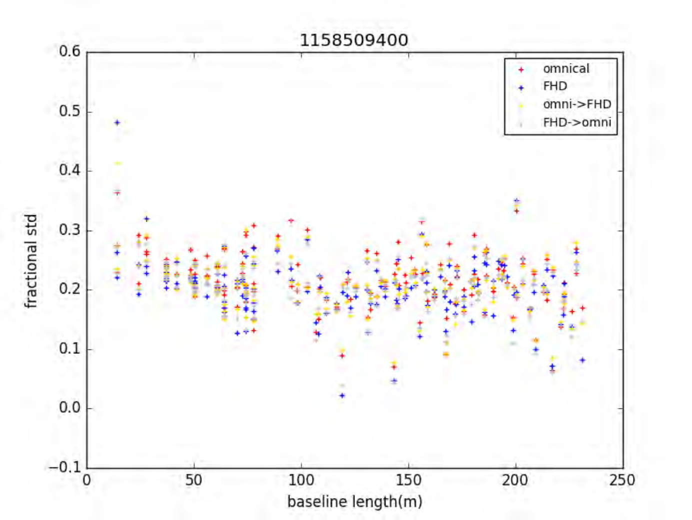


Figure 10: Fractional redundant visibility std grouped by baseline length at 183.3MHz

Power spectrum difference

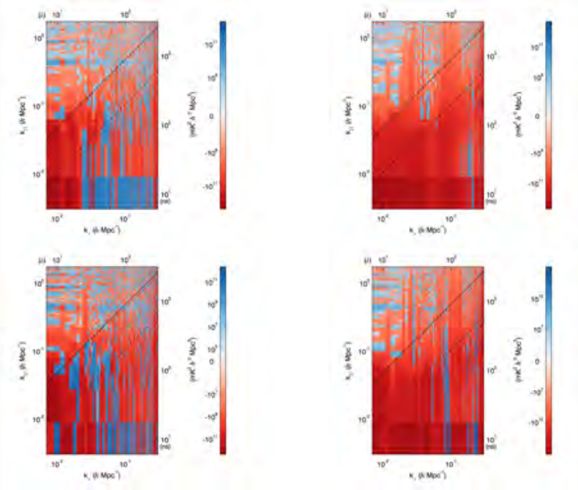


Figure 11: Left column: FHD only minus omnical-FHD; Right column: FHD only minus FHD-omnical

Some thoughts

1. omnical-FHD: Only hex tiles are calibrated before FHD, hex tiles and non-hex tiles should be treated differently
2. FHD-omnical: Take solutions from FHD as a model, feed it into linearized calibration
3. This is the worst case scenario for omnical because it's running blind to MWA PhaseII array and it has never been optimized yet.
4. Do tests on EoR1 or other field with complicated structure which is difficult to calibrate with a point source catalog
5. Optimize omnical solutions by averaging over time or using chi square method more effectively.
6. More suggestions?

References

1. Liu, Adrian, et al. "Precision calibration of radio interferometers using redundant baselines." Monthly Notices of the Royal Astronomical Society 408.2 (2010): 1029-1050.
2. Zheng, Haoxuan, et al. "MITEoR: a scalable interferometer for precision 21 cm cosmology." Monthly Notices of the Royal Astronomical Society 445.2 (2014): 1084-1103.
3. Sullivan, I. S., et al. "Fast holographic deconvolution: A new technique for precision radio interferometry." The Astrophysical Journal 759.1 (2012): 17.

Questions?