Estimates for the Sky Polarization Intensity at $\sim$150 MHz averaged over Wide Solid Angles

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Summary

The MWA maps provided by Emil correspond to the polarization intensity, $|P|$, and rotation measure, RM, in the EoR0 field. It is not clear what frequency $|P|$ is associated to, but since the original data cubes used to produce these maps are $\sim$ 30 MHz deep it could be that $|P|$ corresponds to the highest polarization intensities, in every pixel, over this bandwidth, and hence the file name *peak.fits*.

The exercise presented here intends to show the level of structure that could be introduced to the global 21-cm measurement by the averaging of diffuse polarization over a given beam solid angle, in a range of frequencies.

The complex sky polarization is:

$$P(\nu) = |P| e^{2i \cdot \phi(\nu)} \tag{1}$$

where $\phi(\nu) = \phi_0 + \mathrm{RM} \cdot \lambda^2$ is the map of polarization angles, ϕ_0 are the angles at some reference frequency, and $\lambda = c/\nu$.

The frequency range considered is $100 - 200$ MHz. Since no ϕ_0 was provided, it is assumed to be $\phi_0 = 0$.

A circular, top-hat beam of constant solid angle in frequency is used to compute the average polarization intensity at each frequency. It is computed as:

$$\left| \langle P(\nu) \rangle_\Omega \right| = \sqrt{\langle Q(\nu) \rangle_\Omega^2 + \langle U(\nu) \rangle_\Omega^2}, \tag{2}$$

where $\langle \cdots \rangle_\Omega$ represents averaging over beam solid angle. The Q and U polarization components are computed from the complex polarization maps as:

$$Q(\nu) = real(P(v)) \tag{3}$$

$$U(\nu) = imag(P(v)). \tag{4}$$

Spectral structure could be expected due to different RMs across spatial coordinates. This results in different shifts in polarization angles as a function of frequency for the pixels within the beam solid angle.

Polarization Intensity

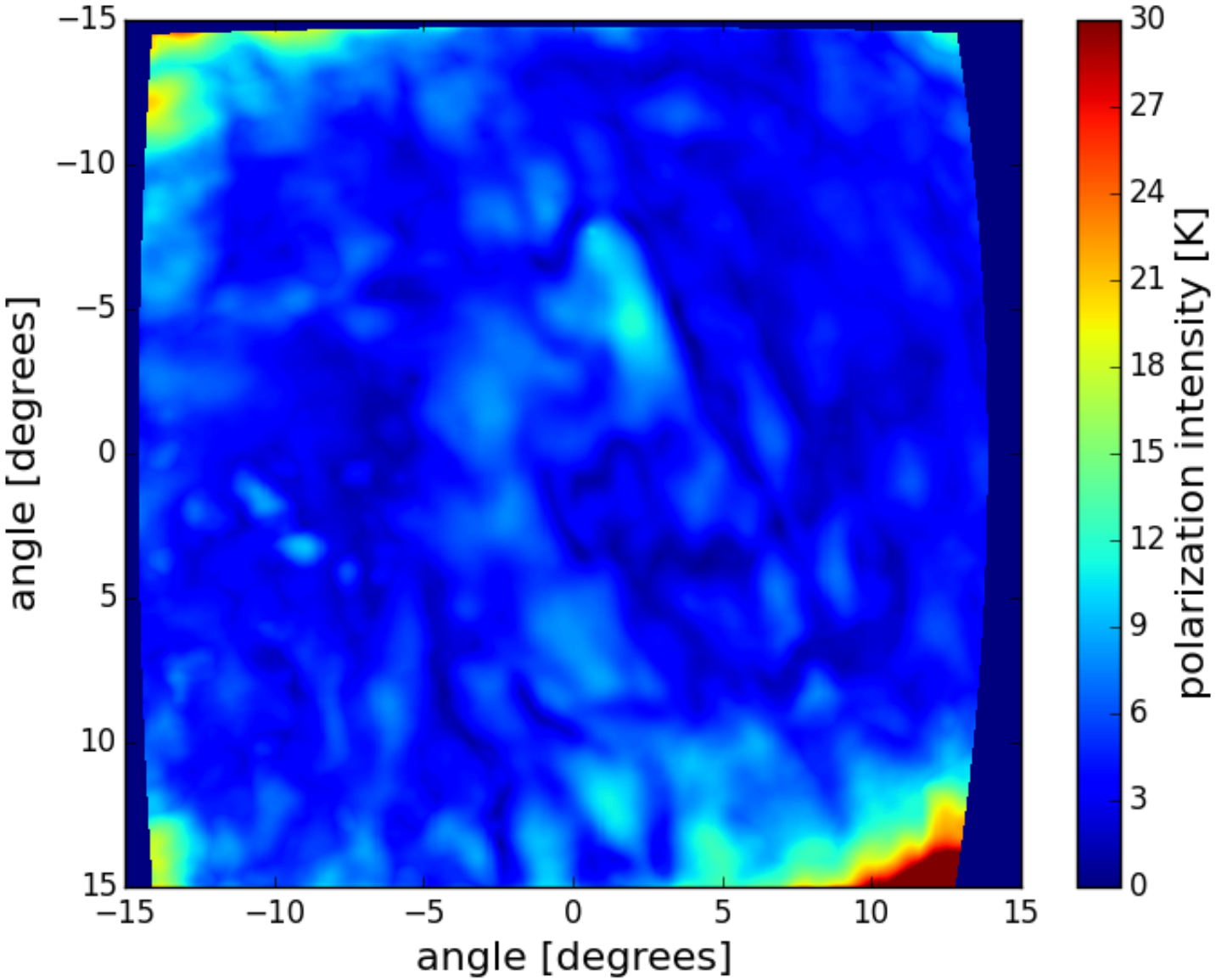

Figure : (1): Polariation intensity map from MWA EoR-0 field.

Rotation Measure

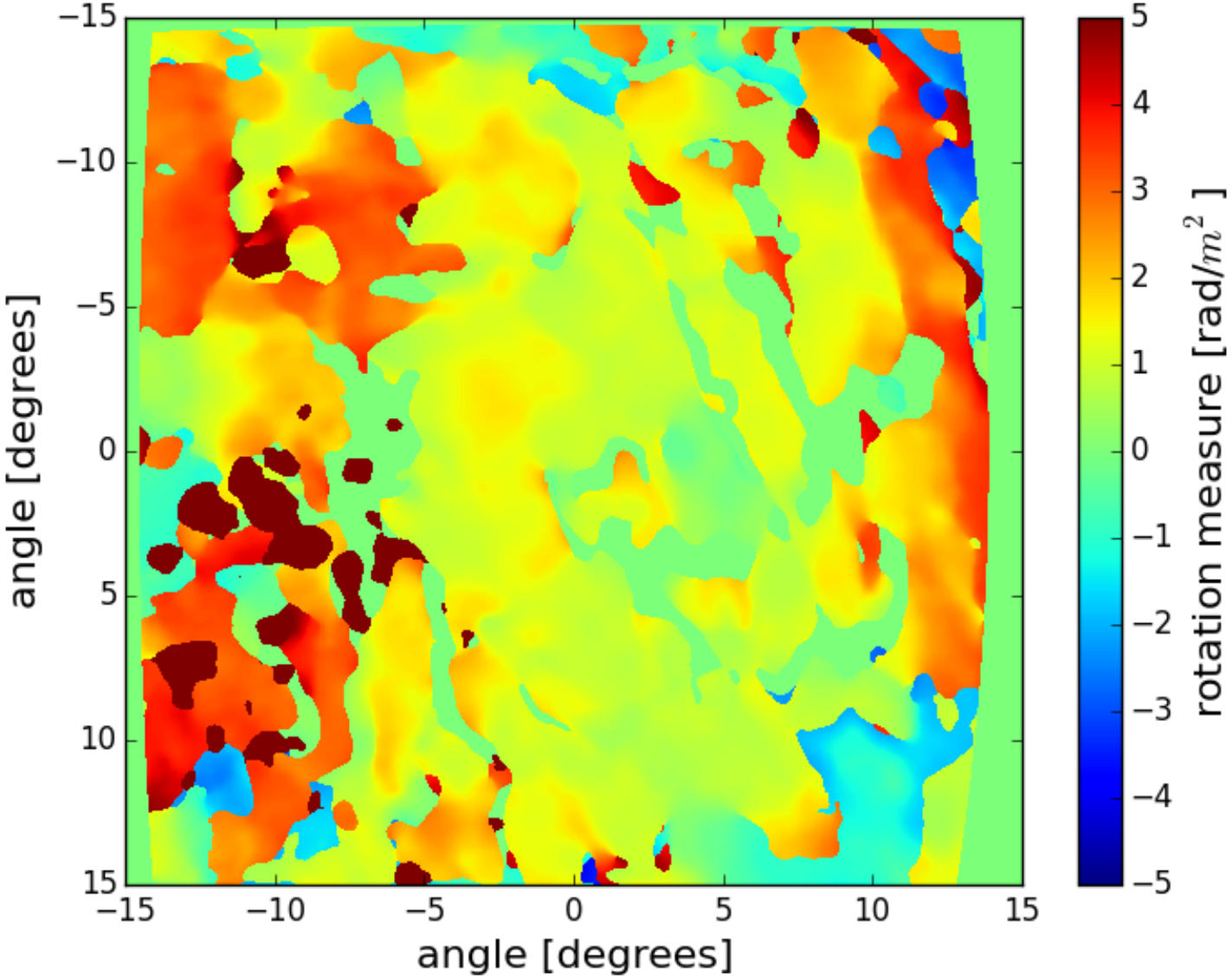

Figure : (2): Rotation measure associated to MWA EoR-0 field.

Spectral Structure, Correlated ϕ_0

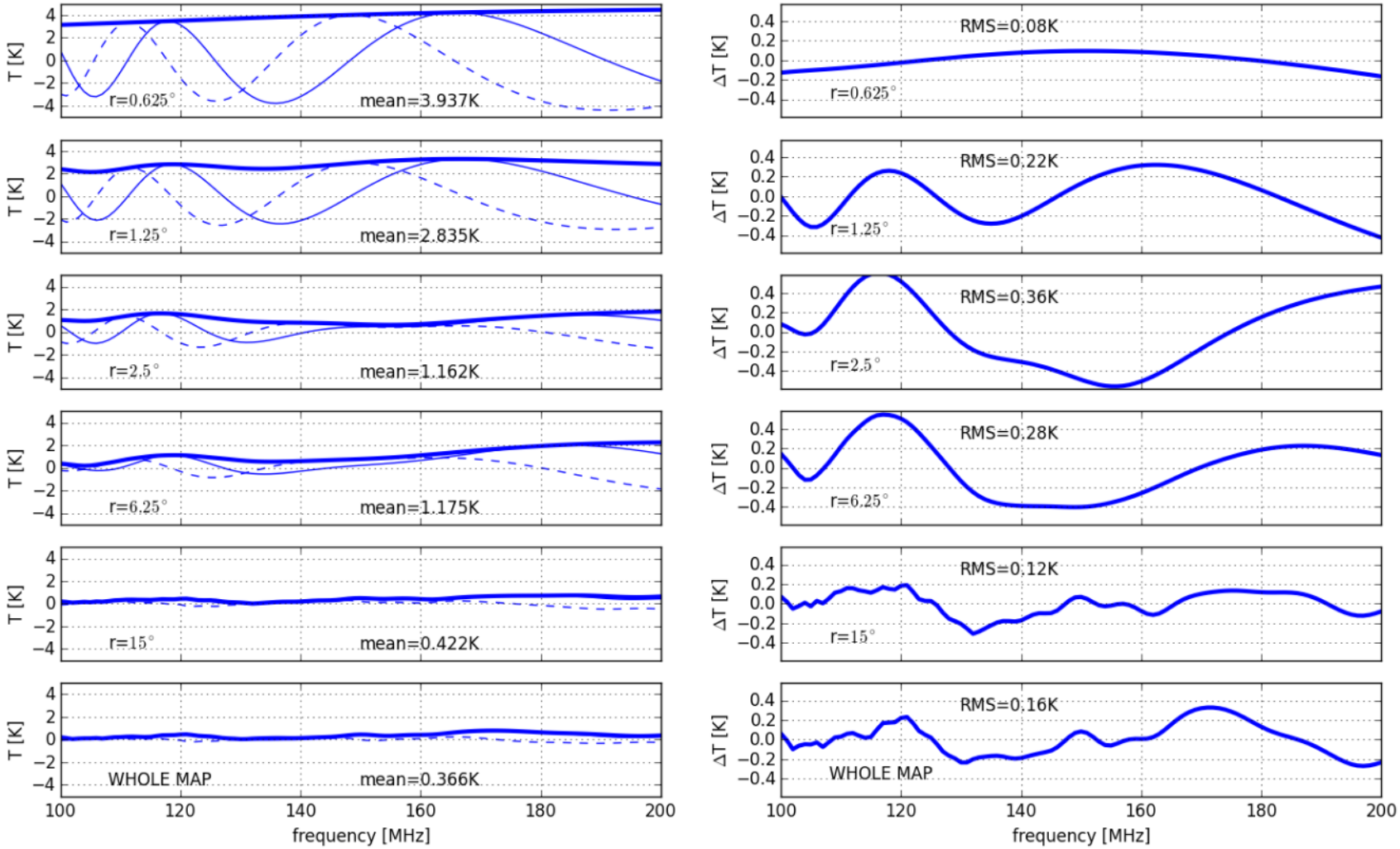

Figure : (3): LEFT: Average polarization intensity for top-hat beams with different radii (between $r = 0.625^\circ$ at the top and the whole map at the bottom) centered at the center of the map. The average is computed with equation 2 where the frequency response derives from equation 1. The results in this figure are obtained using fully correlated polarization offsets, i.e., $\phi_0 = 0$. The thick lines correspond the average polarization itself. The thin solid lines correspond to Q and the dashed lines correspond to U. RIGHT: Average polarization residuals, for the same beam size cases as the left-hand plots, after removing a line (two parameters).

Spectral Structure, Random ϕ_0

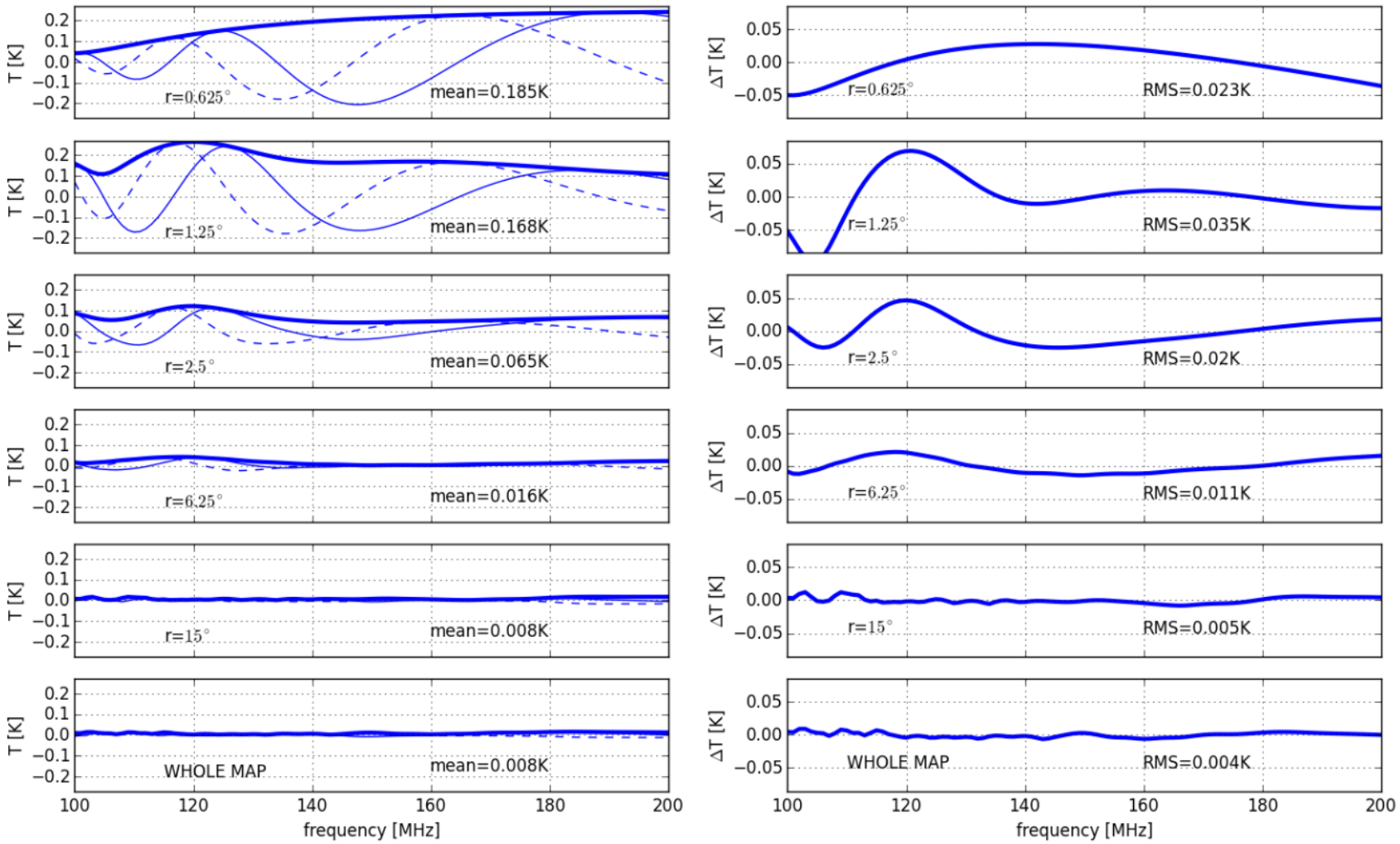

Figure : (4): Same as figure (3), but with random polarization angle offsets. Clearly the averages and RMS structure are significantly lower than when the offsets are assumed as fully correlated.

Comments

- The polarization intensity from the map provided is assumed to be constant in frequency.
- The polarization averaging in space is done using equation 2 instead of directly averaging the polarization intensity map provided.
- Since polarization angles are not available in the 100-200 MHz band, it is assumed that they only vary due to rotation measure. This is not necessarily the case in reality.
- Two extreme assumptions, fully correlated and fully uncorrelated polarization angle offsets, provide limits to potential spectral structure, given the frequency-independent beam assumed and the maps of polarization intensity and rotation measure provided.
- Clearly, fully uncorrelated angles average down to much lower temperatures (8 vs 366 mK for the full map) with much lower structure RMS (4 vs 160 mK for the full map).
- These results and numbers are only applicable to the EoR-0 map and assumpions described.

Extra Excercise

Just for reference, I averaged an absolutely calibrated polarization map from the DRAO 26-m telescope northern sky survey at 1.41 GHz [1].

The averaged was done in Q and U, using equation 2, in galactic coordinates, in a range of latitudes between the north galactic pole and some lower latitude limit, and across 360 degrees of galactic longitude.

The map and averaging results are presented next.

[1] *An absolutely calibrated survey of polarized emission from the northern sky at 1.4 GHz*, M. Wolleben, T.L. Landecker, W. Reich, R. Wielebinski, A&A, 2006, Vol. 448, pp. 411-424.

Polarization Intensity at 1.41 GHz

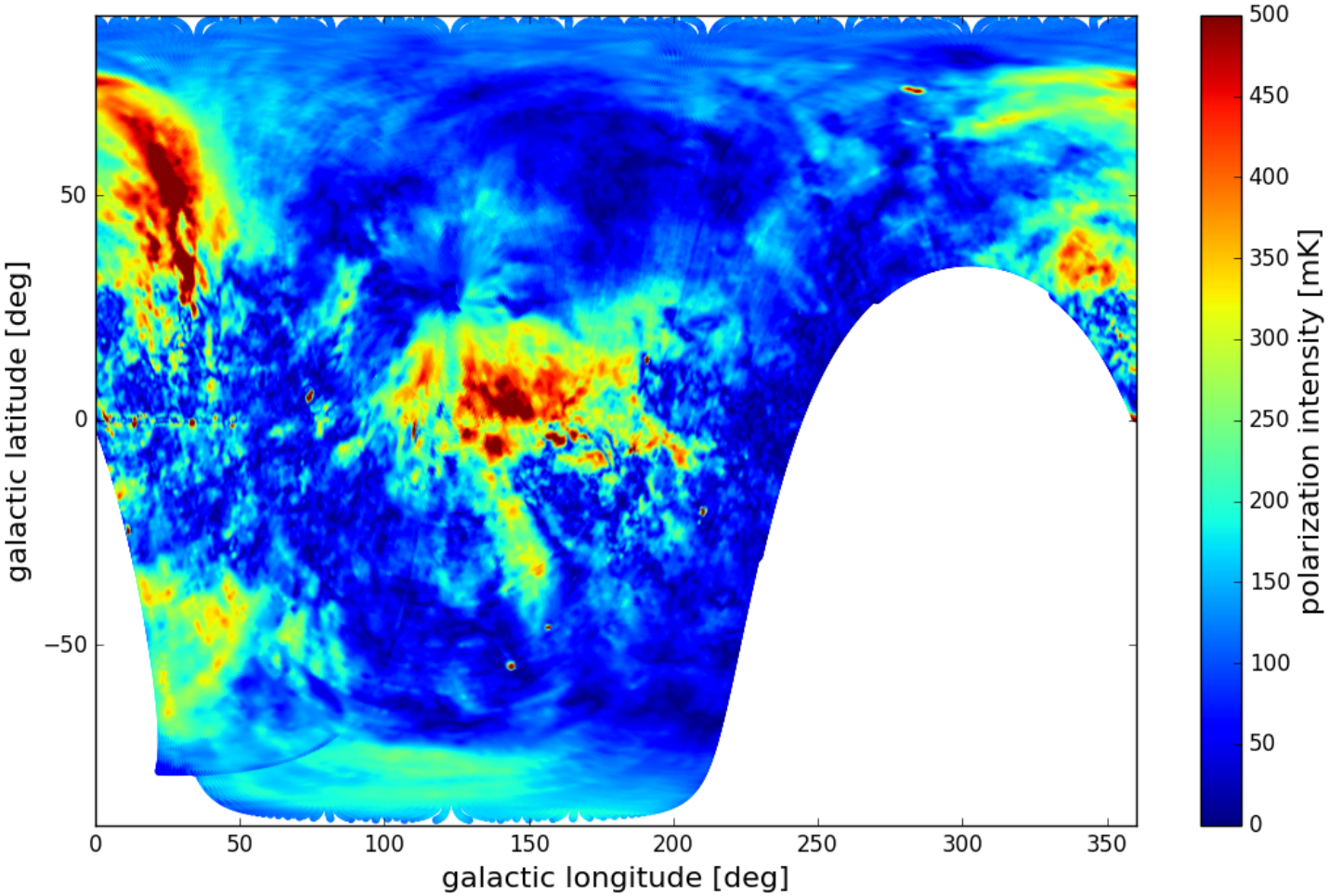

Figure : (5): Polarization intensity from the DRAO 26-m survey in galactic coordinates.

Average of Polarization Intensity at 1.41 GHz

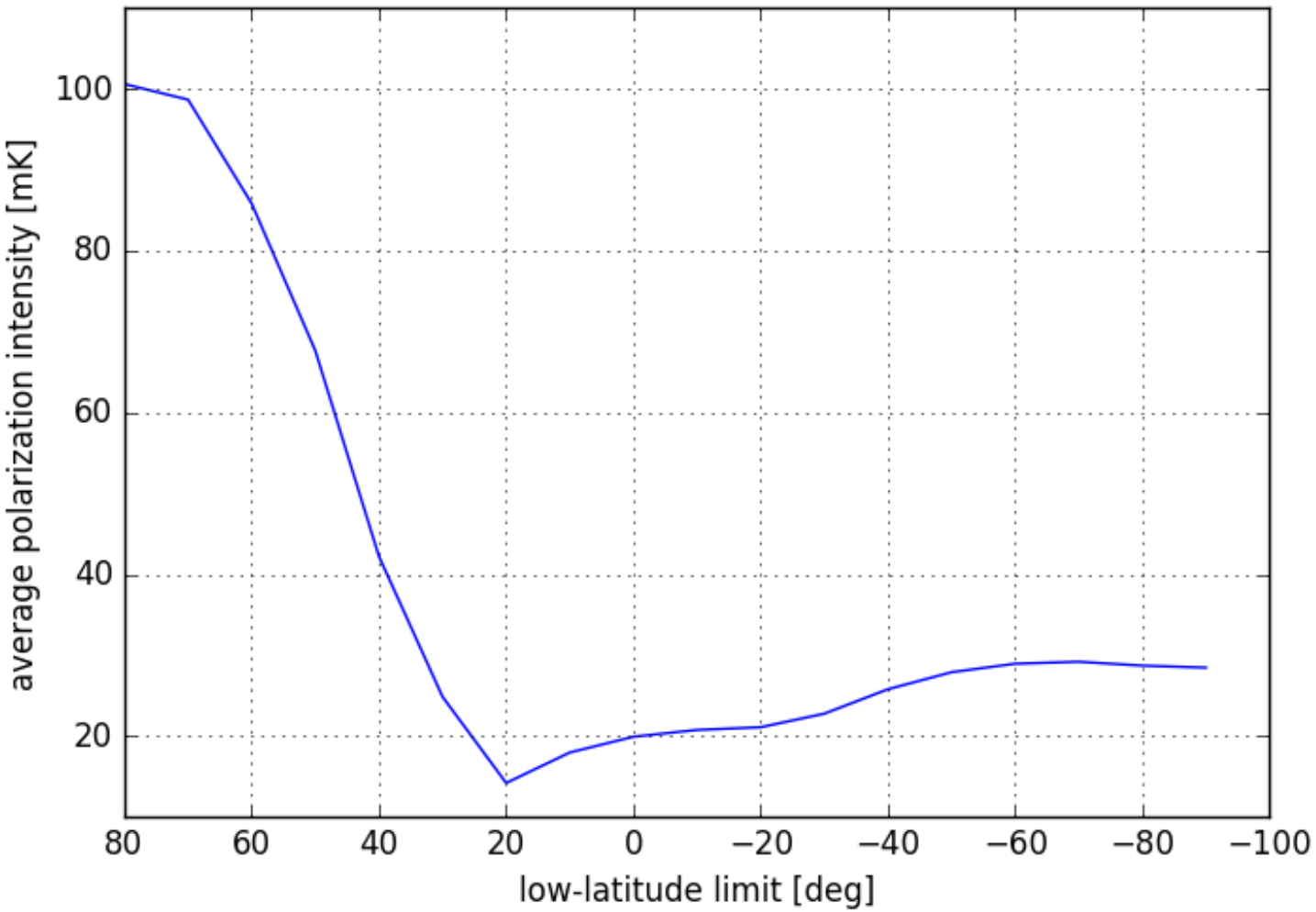

Figure : (6): Polarization intensity average, computed using equation 2, in regions of 360° across galactic longitude, and between +90° and the low-latitude limit in galactic latitude.