MUSTANG-2 Mapping Speeds

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1 Introduction

As the science cases using MUSTANG-2 broaden, so too do the desired scanning strategies. Now that a few projects have pioneered different scan sizes, it is worth assessing the different scanning speeds achieved. A similar analysis was performed nearly a year ago in which scans from 2017 through 2019 were analyzed, and differences between 2.5 arcminute and 3.0 arcminute scans were asses, especially in the context of observing galaxy clusters.

In this analysis, we do not consider (spatial/angular) filtering of the desired astronomical signal as in that study. We expect the filtering to be gentler for larger scan patterns. That is, we expect to recover more large-scale signal with the larger scan patterns, but this has not yet been quantified.

Rather, in this study, we focus on the noise achieved with these scans. When mapping large enough areas, the benefit in mapping speed will be sufficient to argue for a single large scan pattern rather than a mosaic of smaller scan patterns.[1]

2 Overview

Recently, over 3000 Lissajous daisy (LJD) scans have been reprocessed in a uniform manner so as to assess the mapping speeds for different LJD scan radii. Moreover, they are scaled to the average zenith opacity across all semesters and an assumed observing elevation of 45 degrees.

Scan Radius	Mapping Speed $r < 2'$ (μK hr$^{1/2}$)
2.5	73
3.0	74
3.5	77
4.0	85
4.5	98
5.0	117

Table 1: Scanning speeds are taken as an RMS, scaled by scan duration, within a circular aperture of 2 arcminutes, scaled to $\tau_Z = 0.1$ and assuming an observing elevation of 45 degrees.

The mapping speed within the central 2 arcminutes is a fairly useful simplification of the map noise, especially as for scan radii less than ~ 3 arcminutes this region has fairly uniform map noise. These numbers are reported in Table 1. However, as can be seen in Fig. 2, the noise is less uniform as the scan radius increases.

The mapping speed profiles have been parameterized as follows:

$$MS(r) = \sqrt{2} * [A + B * r + C * exp(r/D)], \quad (1)$$

where, for a scan radius $R_{\rm LJD}$, we have:

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[1]NB. It may still be desirable to perform offset scans, as the primary goal here is not to spread out coverage, but to help constrain residual atmospheric noise.

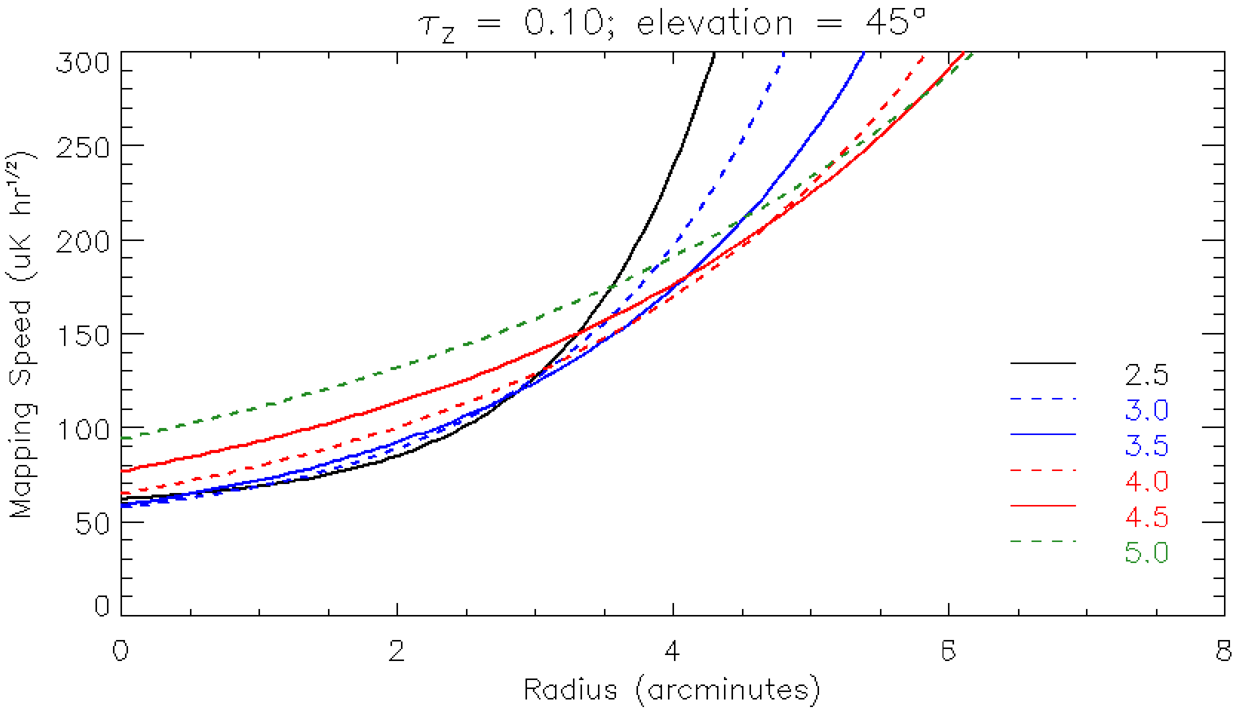

Figure 1: Averaged mapping speeds, scaled to a zenith opacity $\tau_Z = 0.1$ and observing elevation of 45 degrees.

$$A = 137.316 - 53.4331 * R_{\mathrm{LJD}} + 7.63356 * R_{\mathrm{LJD}}^2,$$
$$B = R_{\mathrm{LJD}} - 1.5,$$
$$C = R_{\mathrm{LJD}} - 1.5, \text{ and}$$
$$D = R_{\mathrm{LJD}} * 9.3 - 21.$$

We remind the reader that this gives a mapping speed profile for $\tau_Z = 0.1$ and an observing elevation of 45 degrees. This choice to normalize to this is largely set by the average of zenith opacities over the past 4 seasons (9 semesters) of observations with MUSTANG-2 on the GBT. As evidenced in Fig. 2, semester 21A has been better, on average, than previous semesters.

As this parameterization has been established on scans between 2.5 and 5.0 arcminutes, this is not guaranteed to properly characterize the mapping speed profiles for larger scans. **We do not recommend applying this parameterization to scans larger than 6 arcminutes.**

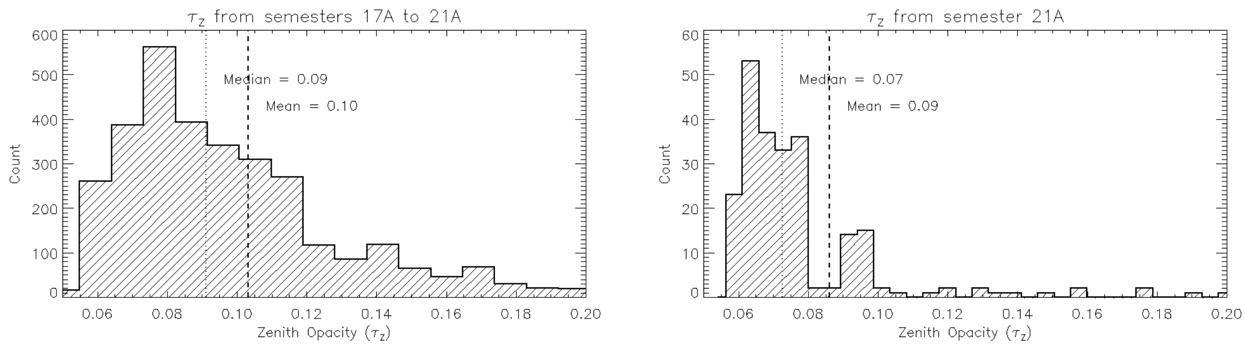

Figure 2:

3 Signal Filtering

We have not fully parameterized the nature of filtering of (astronomical) signals. An earlier analysis compared scans of radius 2.5 arcminutes to 3.0 arcminutes: http://www.gb.nrao.edu/mustang/Observing_with_MUSTANG_2_Executive.pdf. It was found that the two scan radii are largely interchangeable with regards to total signal-to-noise of galaxy clusters of appropriate size.

Clearly, the size of one's target will dictate a range of acceptable scans. We encourage observers to propose for scans that extend beyond the largest radii where signal is attempting to be recovered. For example, if an observer desires to map a target out to a radius of 3 arcminutes, we would recommend a scan radius **greater than** 3 arcminutes, e.g. 3.5 arcminutes or more. In a scenario where two scans give comparably acceptable noise (mapping speed) profiles, the MUSTANG-2 team recommends going with the larger of the two scans as the astronomical filtering should be less.

In lieu of a publicly available means of calculating a filtered astronomical signal, the MUSTANG-2 team will work with observers to estimate the filtered signal.