SPIRE

Scan Map Scanning Angles and Separations

Prepared by: Tim Waskett
Bruce Sibthorpe

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Contents

1. Introduction

This document describes the possible scanning angles that could be utilised during the SPIRE scan map mode.

Two sets of angles are defined: one that produces Nyquist frequency samples, that is, samples spaced in such a way that the spacing between two neighbouring points is no more than half of the beam FWHM; and one that produces double Nyquist samples, or one quarter of a beam FWHM. Both angles are compared in relation to sky coverage during a single scan leg. Full sky coverage is traditionally defined to be Nyquist sampling, so both of these possibilities give a fully sampled map, it is simply the distribution of those samples that is different.

2. Scan Angle Definition

For the purposes of this document scan angles are defined in relation to one of the symmetry axes of the SPIRE arrays (see schematic.) Because the detectors in the SPIRE arrays are hexagonally close-packed the arrays have 3 symmetry axes giving rise to 6 fold rotational symmetry (ignore the rectangular nature of the arrays for now.) The scanning angle, θ, is the angle that the array travels in relation to one of these symmetry axes in order to achieve a fully sampled map (also see schematic.)

The two angles under consideration here are as follows:
Nyquist angle $\theta = 13.9°$
Double Nyquist angle $\theta = 12.4°$

For the derivation of these angles see [1].

As can be seen from the schematic, there are three unique scan directions that can be used to give a fully sampled map. For simplicity these will now be referred to as long, diagonal and short, for scanning performed close to the long axis, diagonal direction and short axis respectively.

3. Integration Time Maps

The remainder of this document contains maps produced from simulations performed with the SPIRE Photometer Simulator. These maps show the number of data points falling in each map pixel, effectively a representation of the relative integration time experienced across the map; white is zero, black is the maximum. A uniform spread of integration time leads to a more uniform map, in terms of survey depth and noise characteristics. In the following maps the more uniform the grey, the more uniform the sky coverage is.

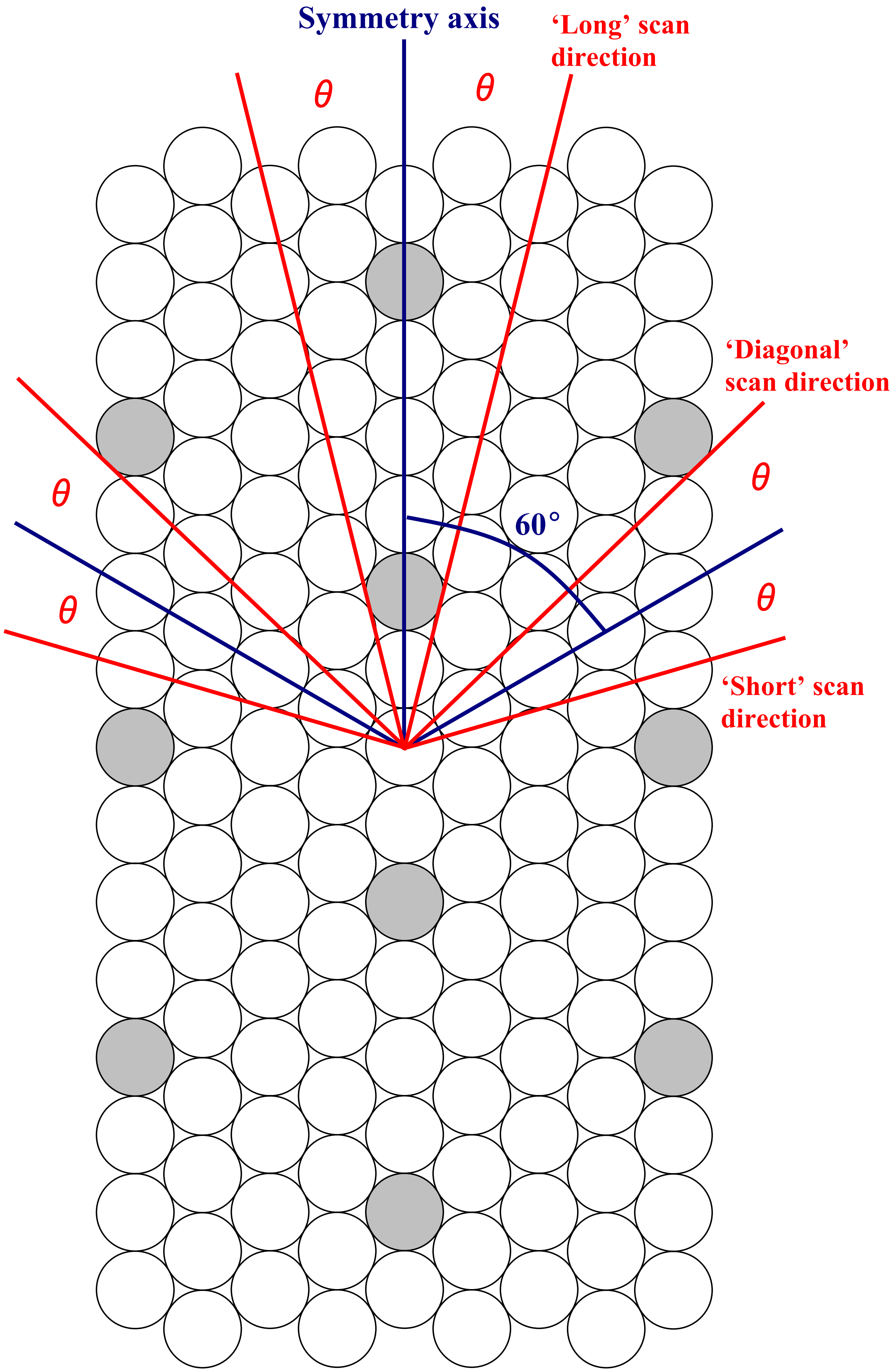
The pixel sizes are all ~ ¼ beam FWHM, so 4”, 6”, 9” for the PSW, PMW, PLW arrays respectively. For comparison, Nyquist sized pixels would be ~ 8”, 11” and 16” respectively (or ¼ of the detector centre-centre spacing.)

4. Summary of Scan Angles

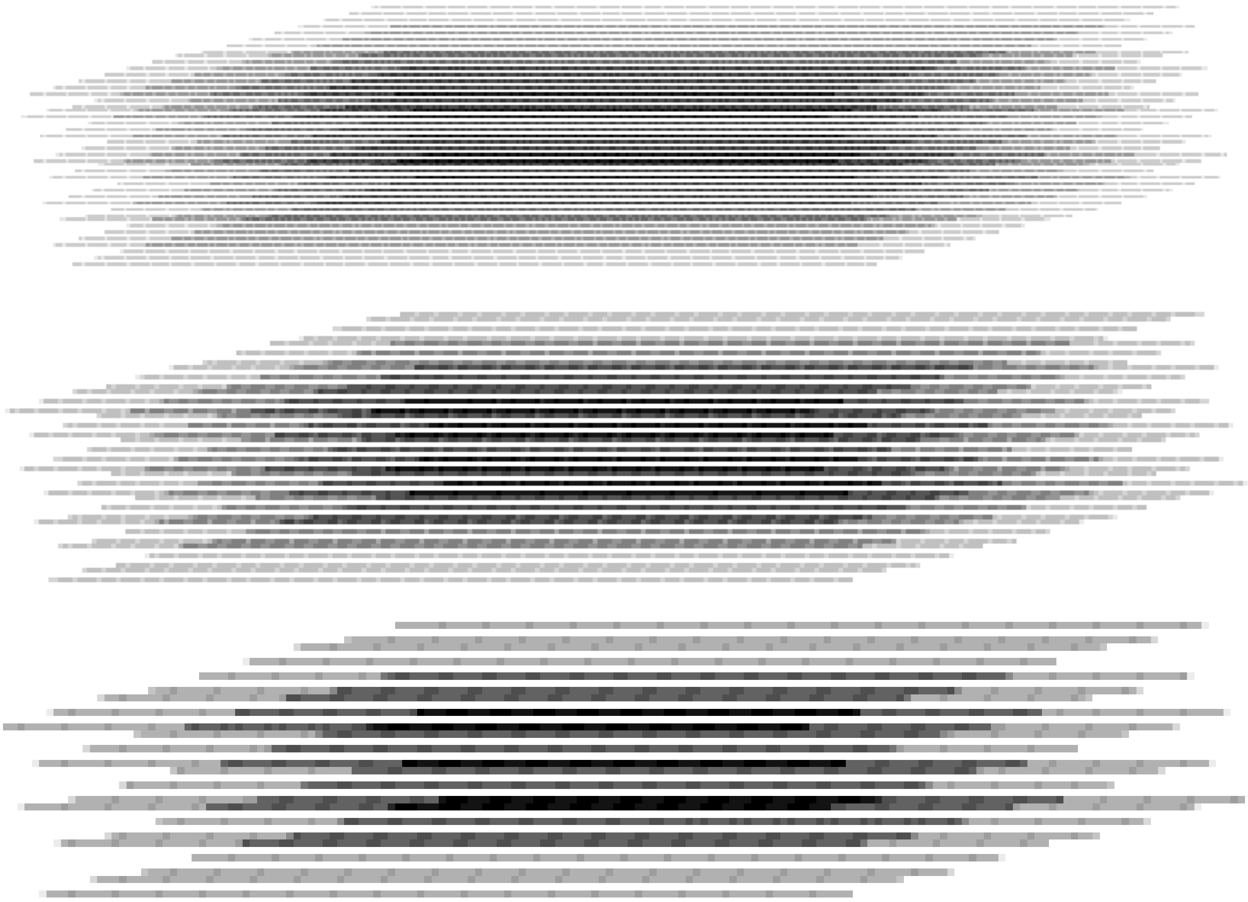
Both Nyquist and double Nyquist angles will give a fully sampled map if binned to pixel sizes of ½ beam FWHM. However, if binning to smaller pixel sizes, as in the following examples, the Nyquist angles will always leave stripes of missing data. The main advantage of this strategy is that many points in the sky will be visited by more than one pixel in a single scan leg (the black and darker grey stripes in the following maps show where this happens.) This may be desirable under certain situations.

The double Nyquist sampling will give fully sampled maps for all three arrays when scanning close to the long axis, and when using the smaller pixel sizes. However, gaps appear in the PLW maps for the diagonal and short directions, and also for the PMW array when scanning close to the short axis. Using larger pixels will alleviate this problem, and the sampling is still at least as good as in the Nyquist sampled case and often better. (Full sampling for the PLW array is achieved with pixel size of 14” for diagonal and short scanning; full sampling for the PMW array is achieved with a pixel size of 9” for shot axis scanning.) The main disadvantage of this strategy is the lower redundancy – that is, fewer points of the sky are visited by more than one pixel in a single scan leg.

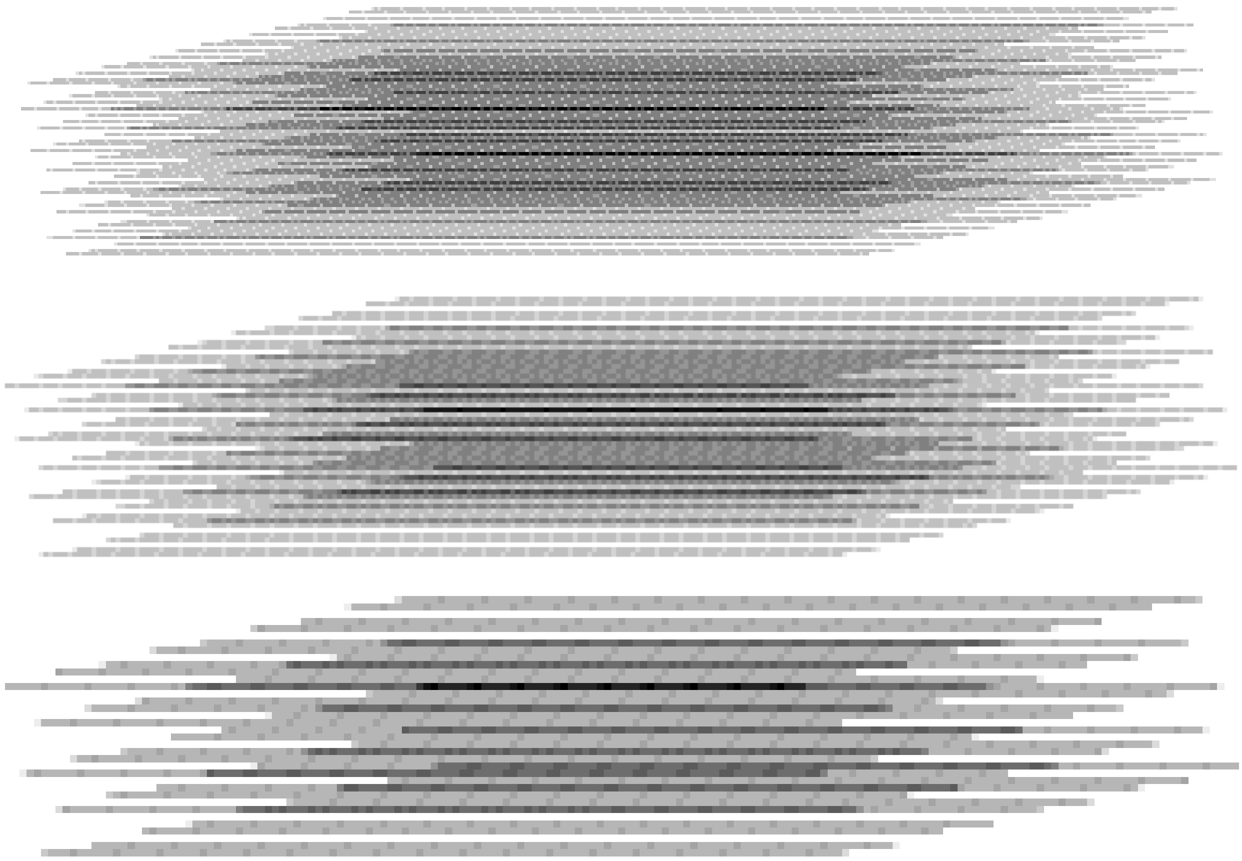
Schematic PSW array.



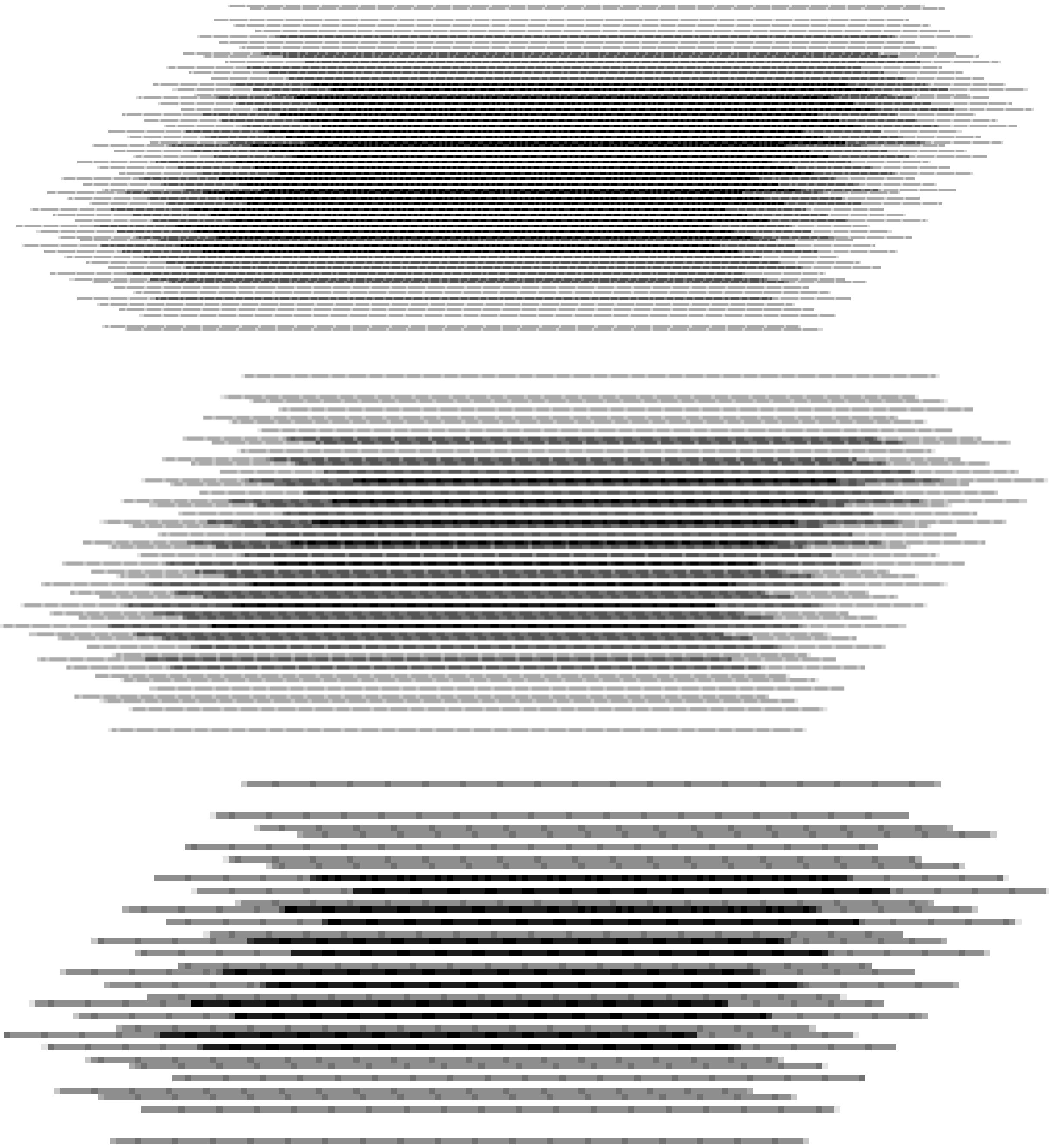
Long axis scanning with Nyquist sampling. PSW: top, PMW: middle, PLW: bottom.



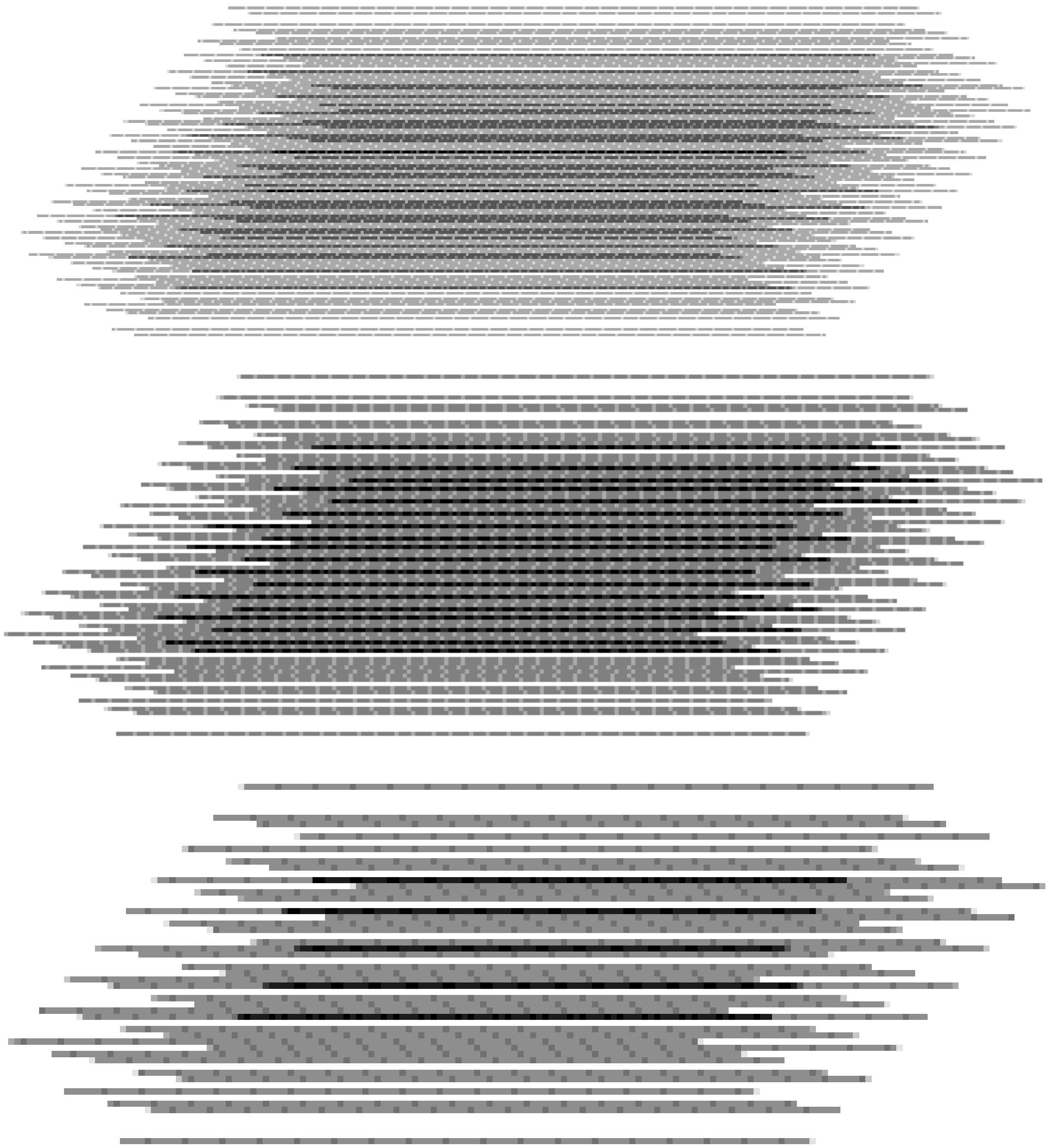
Long axis scanning with double Nyquist sampling.



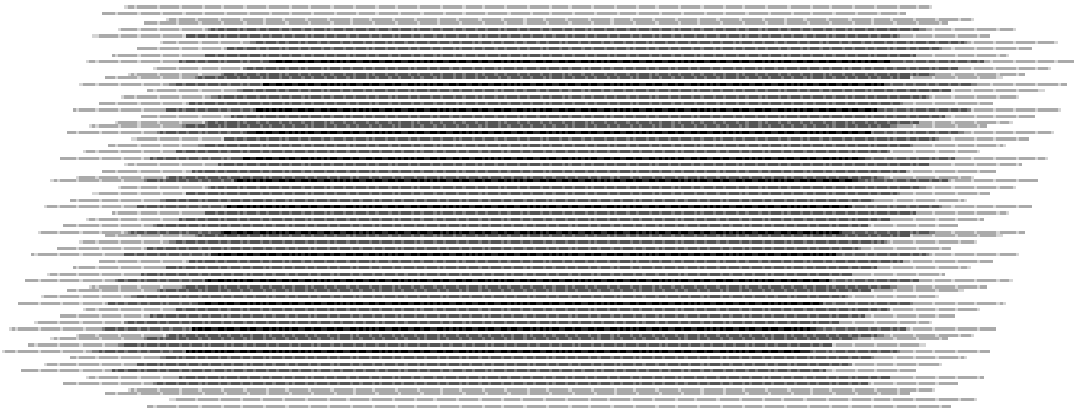
Diagonal scanning with Nyquist sampling.

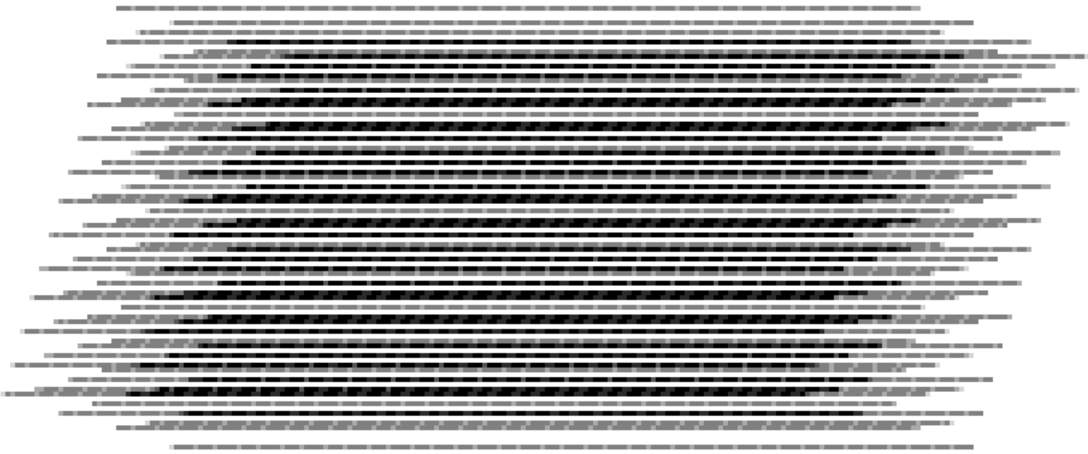


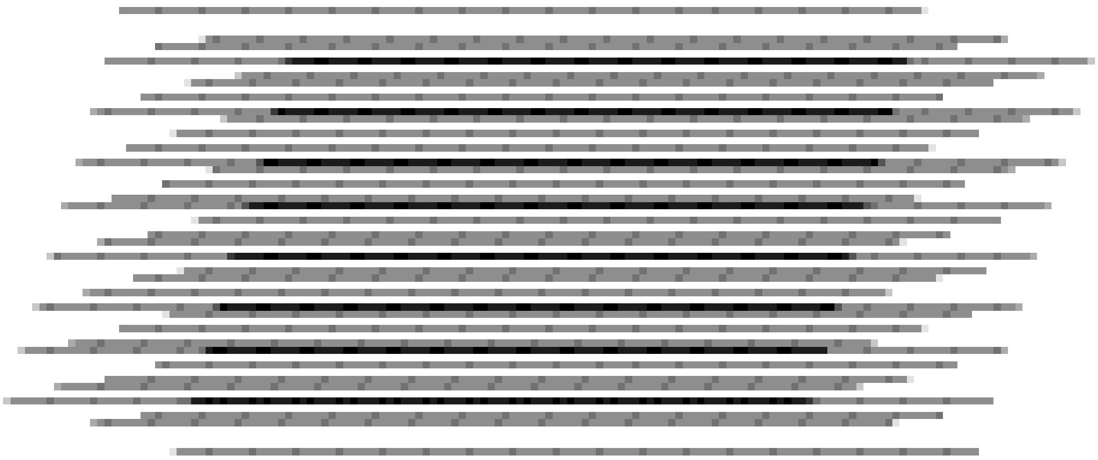
Diagonal scanning with double Nyquist sampling.



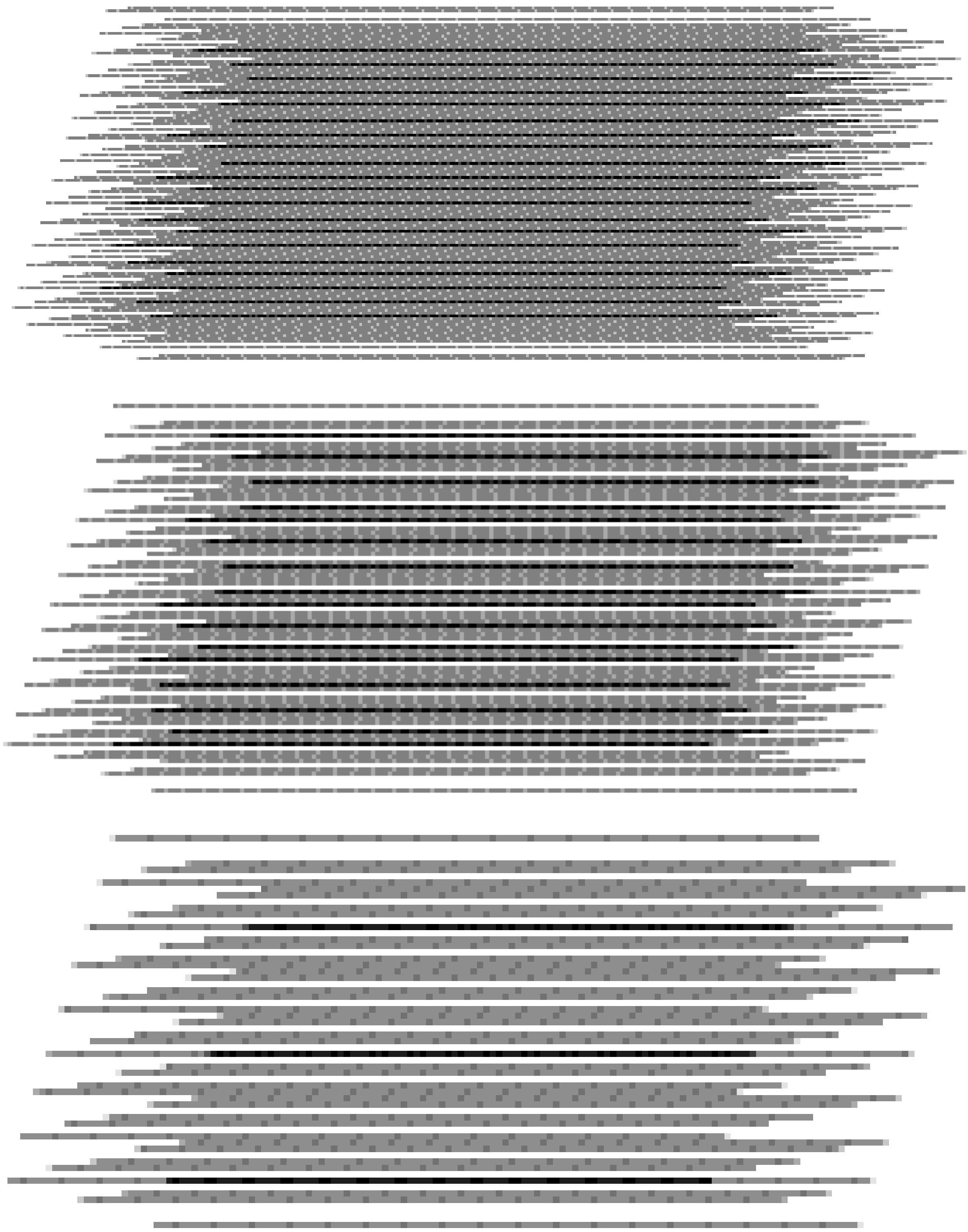
Short axis scanning with Nyquist sampling.







Short axis scanning with double Nyquist sampling.

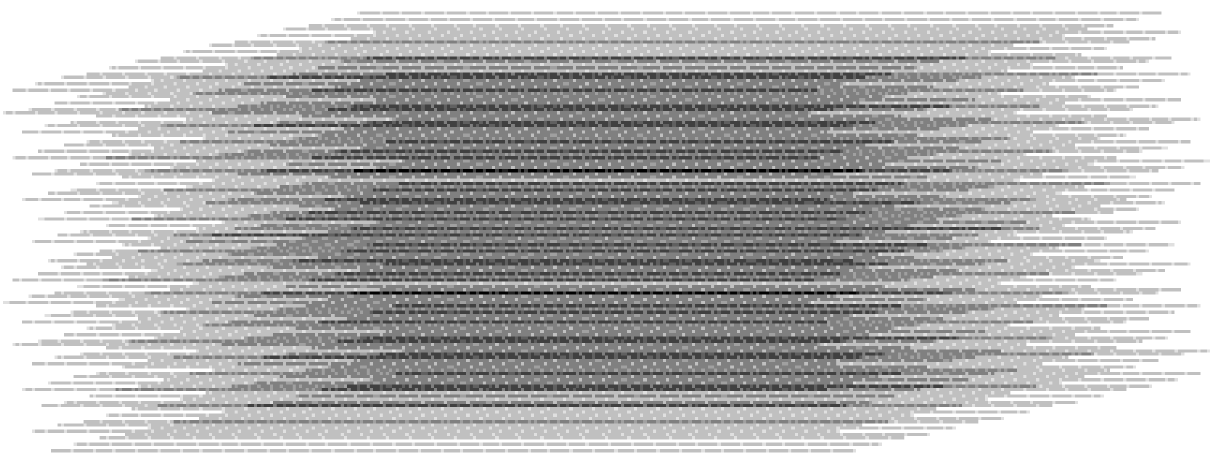


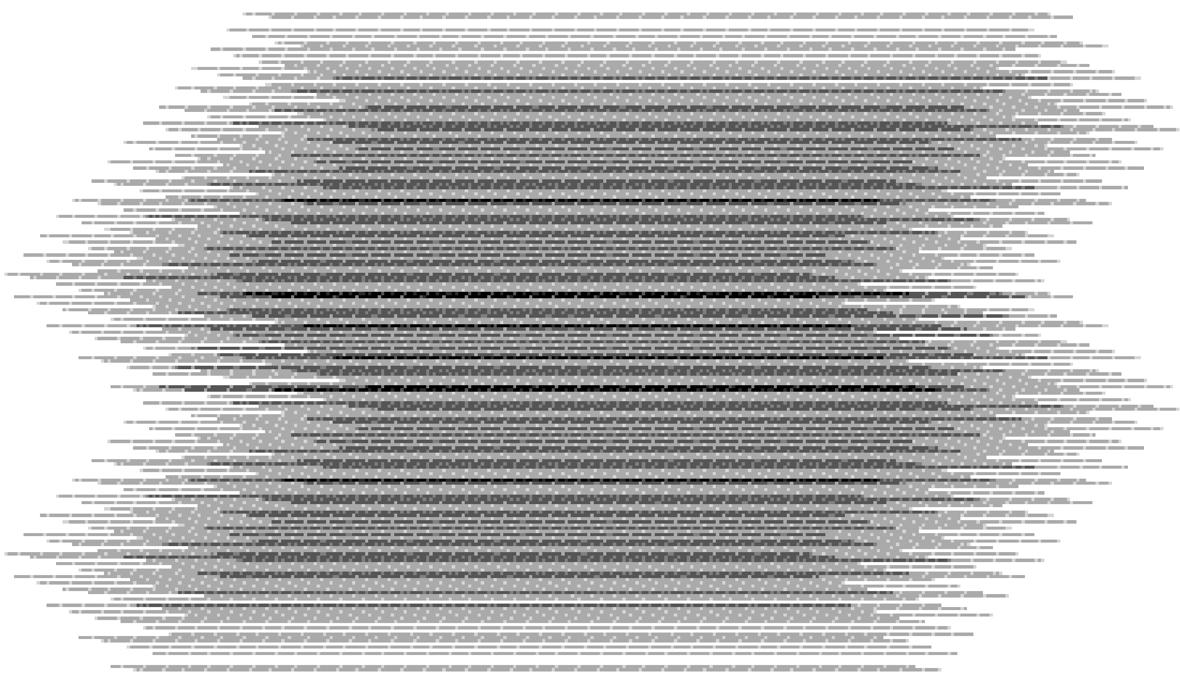
5. Scan Leg Separations

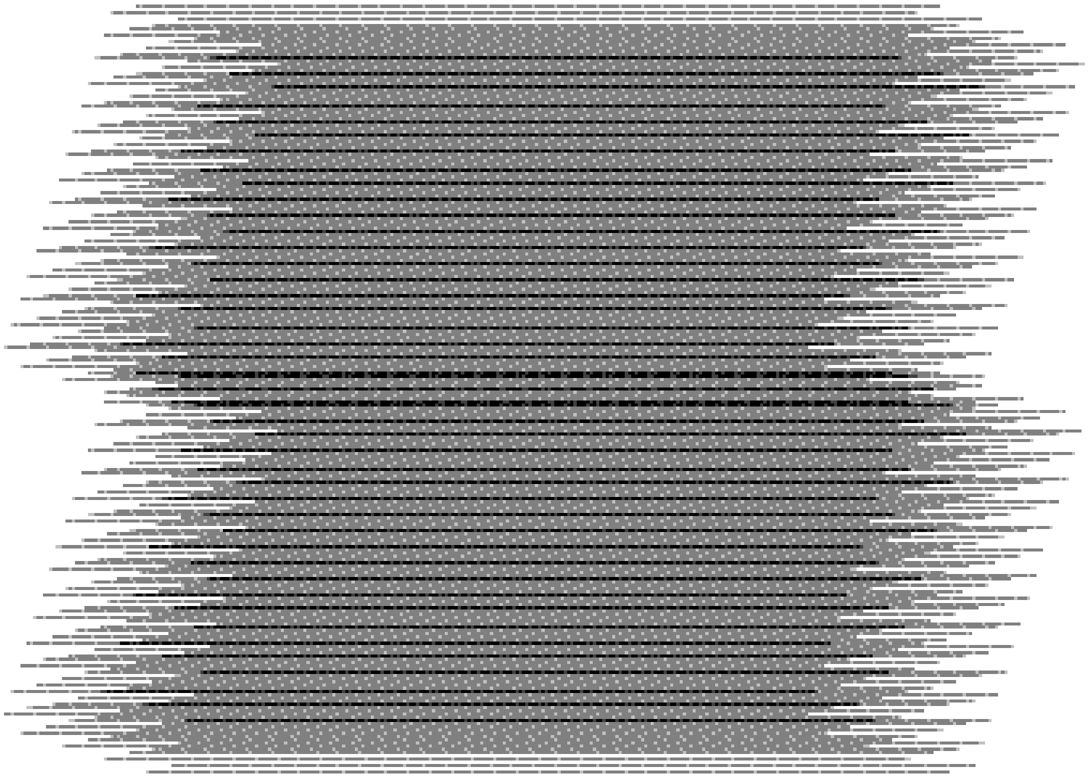
When producing a large map, made up of many scan legs, the separation distance between subsequent scan legs is dependent on the scanning angle selected. These can be summarised as follows (Nyquist angles: top 3, double Nyquist: bottom 3):

Scan Angle w.r.t. long axis (deg)	Scan leg separation (arc sec)
13.9 (long)	233
46.1 (diagonal)	340
73.9 (short)	460
12.4 (long)	235
47.6 (diagonal)	348
72.4 (short)	455

Again, the derivation of these distances is left as an exercise to the interested reader but these separations ensure that the sky coverage of a large map is as uniform as possible. Because the PSW array has the smallest detectors these scan leg separations provide optimum sky coverage for the PSW but a slight excess of coverage in the overlap region for the other two arrays. The following integration time maps show examples of these separations for the PSW array, using the double Nyquist scan angles.







6. Recommendations

Any one of the scanning angles suggested here will give fully sampled and reasonably uniform maps. Nyquist scanning will not allow smaller than ½ beam FWHM map pixel sizes to be used though.

This analysis has assumed 100% detector yield, which is certainly not the case in the real system. Dead detectors will lead to gaps in the maps but scanning close to the long axis will reduce this problem since there are more detectors 'bringing up the rear', as it were, filling in the gaps. Therefore, it is recommended that scanning close to the long axis be the mode of choice in as many observations as possible.

One downside to long axis scanning is the higher overhead time required during turnaround, because the array has to travel further before the entire array has passed over the required map area.. For large maps this will be a minor fraction but for smaller maps it may be better to scan close to the short axis and 'dither' subsequent scans to fill in the gaps left by dead detectors. Since very deep observations tend to be in small areas there will be plenty of map repeats to allow the gaps to be filled in.

Double Nyquist scanning angles provide a highly uniform sky coverage, and some redundancy is present in each scan with several strips of sky being visited by more than one detector (albeit fewer stripes than when scanning at the Nyquist angle.) If it is necessary to scan along either the diagonal or short axes (due to scheduling constraints, or whatever) then double Nyquist scanning still provides a good compromise between uniformity and redundancy.

Because the PSW array is always fully sampled with ¼ beam FWHM pixels during double Nyquist sampling – even for diagonal and short axis scanning – the need for larger pixels for the other two arrays is offset somewhat. For example, source extraction can still be performed on the PSW array using the smaller pixels with the associated higher spatial sampling, and this will support the source extraction in the other two bands, despite the lower spatial sampling. In any case, Nyquist scanning requires larger map pixels than double Nyquist scanning in all situations. Therefore, double Nyquist scanning is recommended, regardless of which axis the scanning direction is closest to.

The recommendations of this report are highlighted in the table above by shaded cells.

7. References

[1] *Determination of Optimum POF5 – Scan Map Parameters*, Bruce Sibthorpe, Tim Waskett, SPIRE-UCF-NOT-002755