SPIRE

Cross Linked Scan Map Observations

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Contents

1. Introduction

This note describes how combining orthogonal SPIRE scan map observations together could be achieved. The actual implementation of this scheme is left to those more qualified to make comment.

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 1, later.) Because the detectors in the SPIRE arrays are hexagonally close-packed the arrays have 3 symmetry axes (the thick black lines in the schematic) 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 three symmetry axes in order to achieve a fully sampled map (also see schematic 1.)

The proposed angle is $\theta = 12.4°$.

The reasoning for this angle is shown in [1].

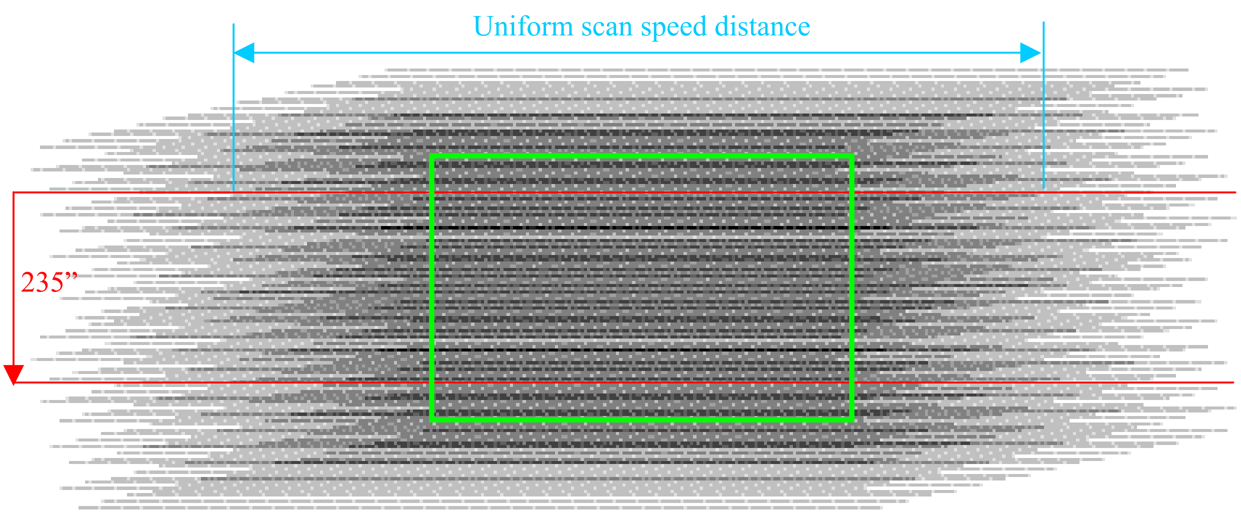
As can be seen from the schematic, there are three unique scan directions that can be used to give a fully sampled map, all other possible scan directions are just reflections of these three basic ones about one of the symmetry axes. For simplicity these will now be referred to as long, diagonal and short, for scanning performed close to the long axis, diagonal direction and short axis respectively.

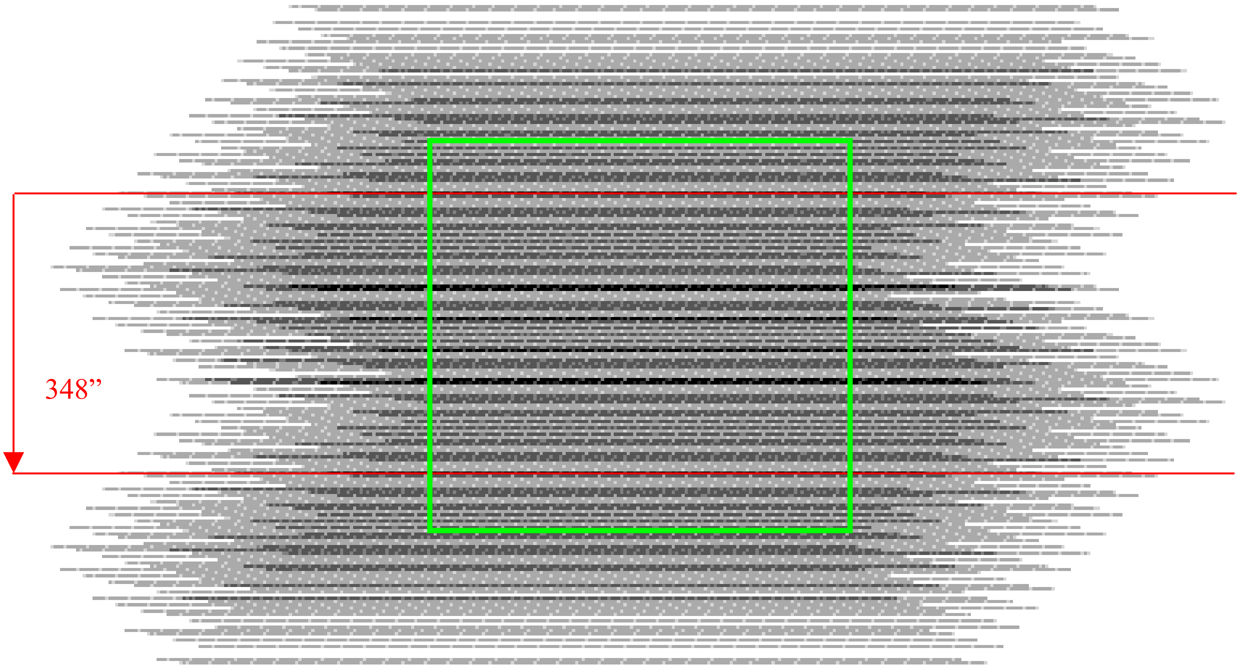
3. Scan Leg Separations

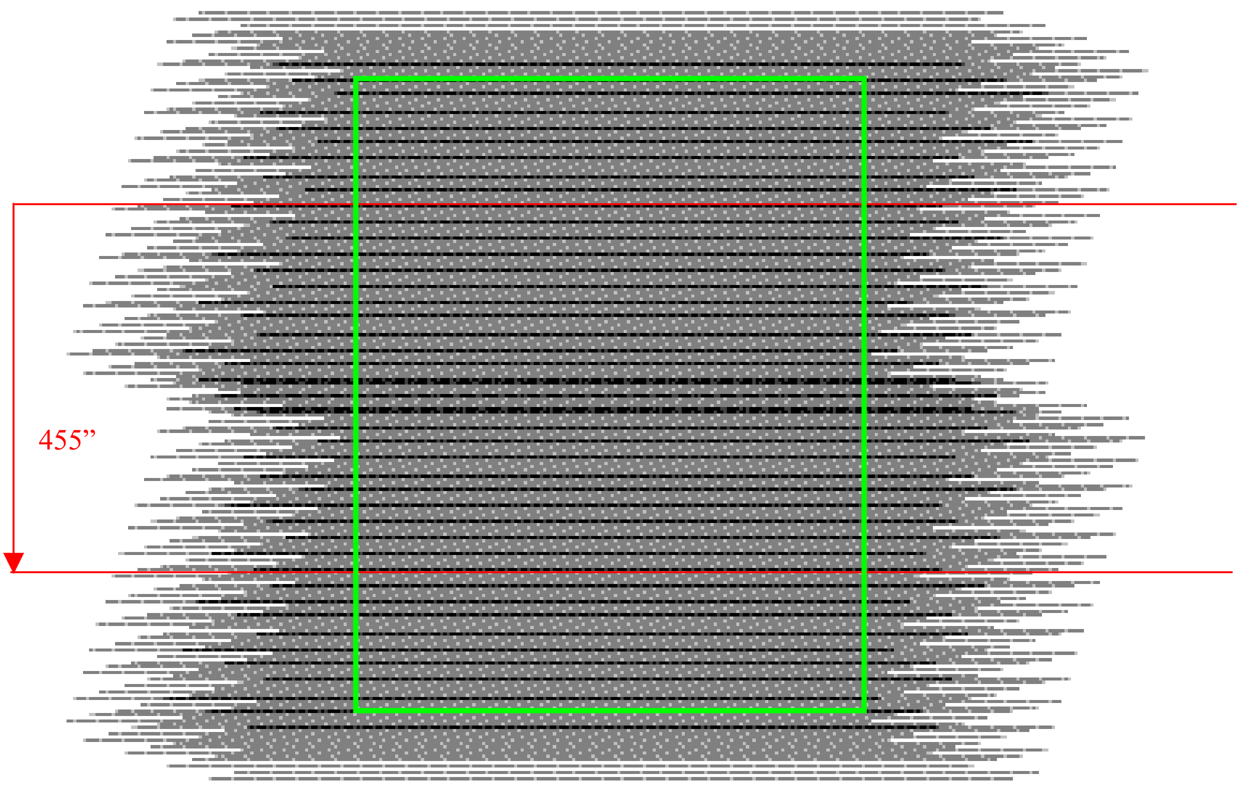
When producing a large map, made up of many scan legs, the separation distance between subsequent scan legs is dependent on the scanning angle selected. These can be summarised as follows:

Scan Angle w.r.t. long axis (deg)	Scan leg separation (arc sec)
+/- 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 (turn around data not included) – the darker the shading the greater the integration time. The red lines passing through the centre of the arrays show the scan legs and how they are separated. The green rectangles show the approximate area of the map that is covered to a uniform depth.



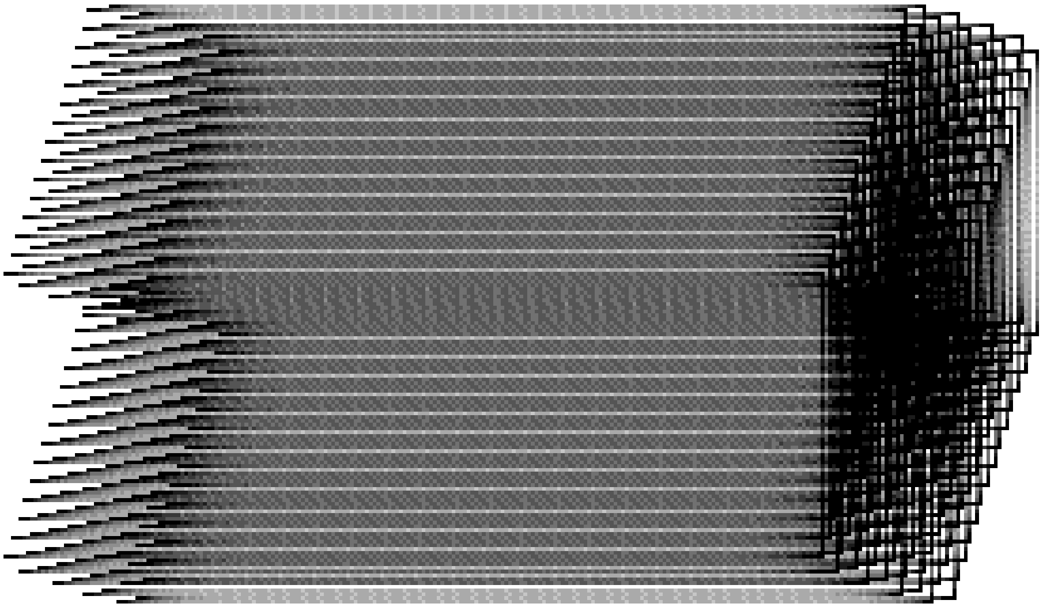




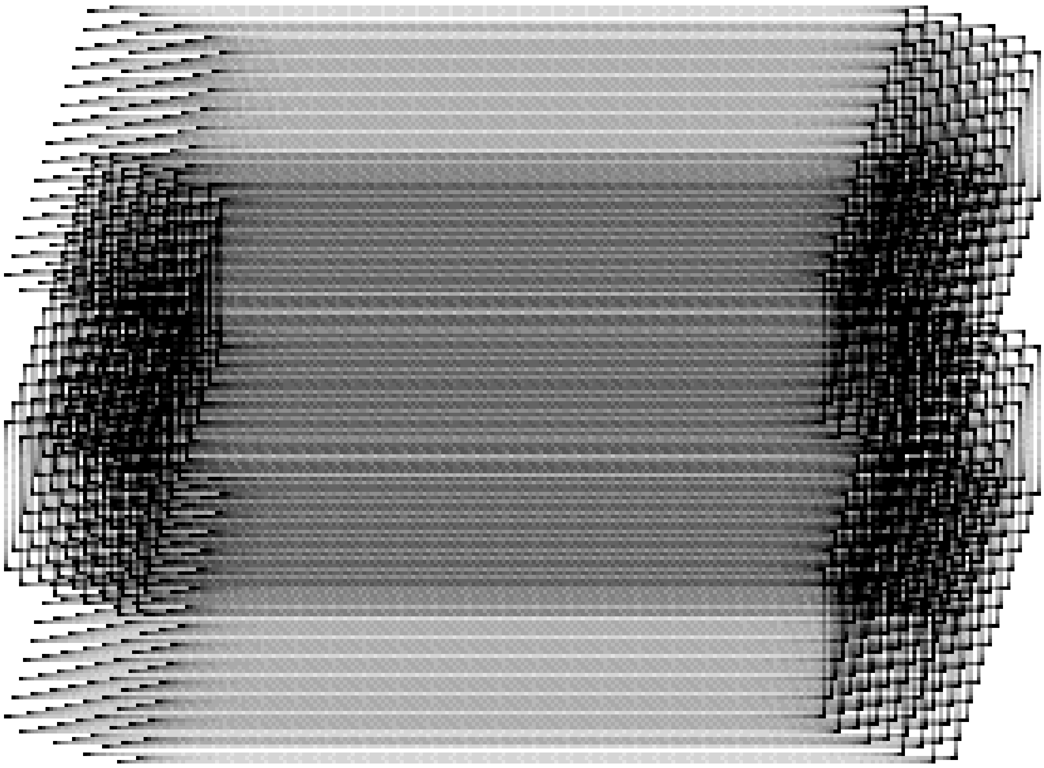
4. Problems with Mixing Parameters

The following examples show how a relatively small map can be seriously affected by choosing the wrong combination of parameters. Here we use short scanning but in one map the appropriate short scanning separation is used, while in the other the inappropriate long scanning separation is used. The first map has two scan legs while the second has 4. In order to equalise the integration time in both examples the first is performed twice while the second is only performed once (turn around data is included this time):

Short axis scanning with short axis overlap parameter.



Short axis scanning with long axis separation parameter.



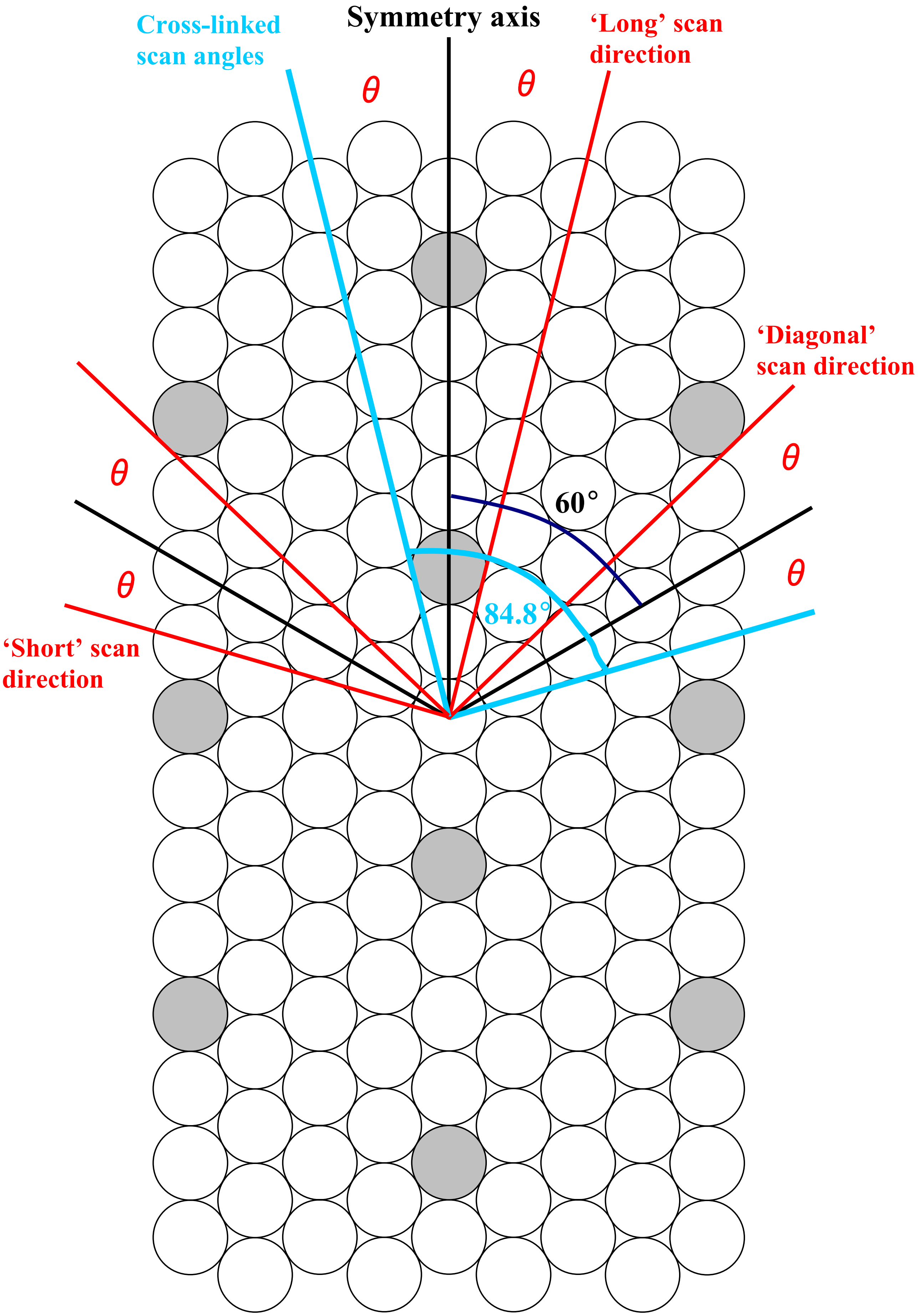
The same colour cuts are used in both of these examples to show the relative integration time.

The second example is clearly less than ideal with two very large strips of data, at the top and bottom, experiencing less (~1/2) integration time than the central region.

5. Orthogonal Scans

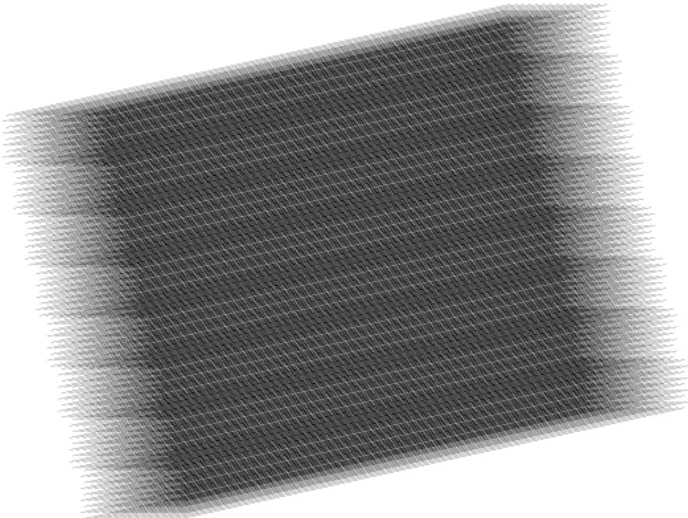
Creating two scan maps with scan direction that are exactly 90° apart is not possible but we can get close by careful selection of the right angles. In schematic 1 two standard scanning directions are highlighted in blue that are separated by 84.8°. One map would be created by long axis scanning while the second would be short axis scanning. The corresponding angles w.r.t. the long axis would be **+12.4°** and **-72.4°**, or the inverse of these.

Schematic 1. PSW array with superimposed scan angles.

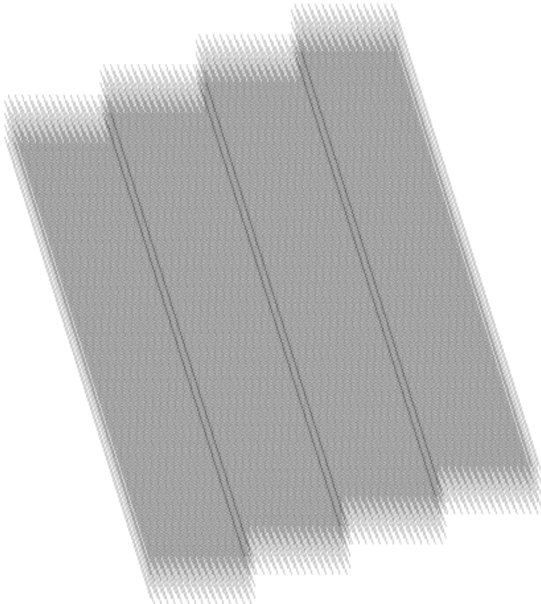


This poses a problem as the integration times for two maps made with these different scan angles would be different, by a factor of 2, more or less. So in order to equalise the integration time between the two different scan geometries the map performed with short axis scanning would need to be repeated twice for every one long axis scan map. The following examples should help to visualise this. Here, the area to be mapped is ~30'x30'. To map this with long axis scanning we need 8 scan legs separated by 235" (giving an actual map area ~28.9' wide due to the discrete nature of adding scan legs together, or we could add one more to make it 32.8' wide; see section 7) and a uniform speed scan length of 39' to allow for the full array to be at full speed across the entire map area (final map area = 30'x28.9'.) Conversely, to map this area with short axis scanning we need 4 scan legs separated by 455" and a scan leg length of 36.3' (final map area = 30'x28.2'.) In both cases the long axis of the array is horizontal to the page.

Long axis scan

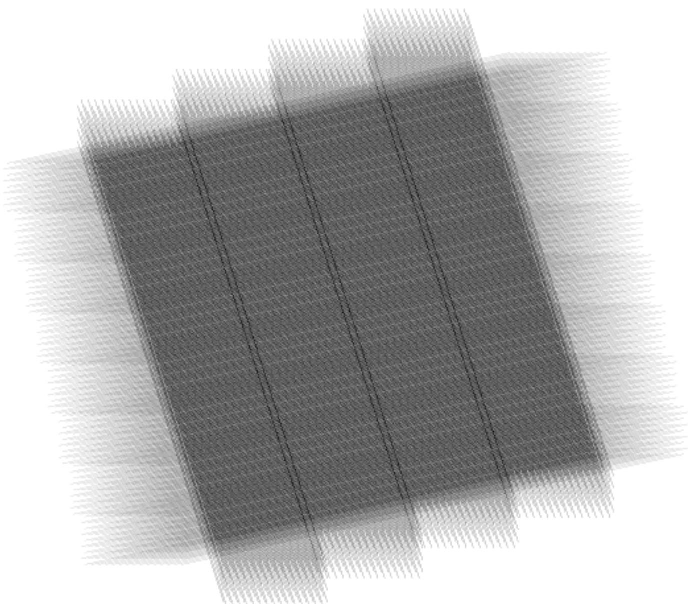


Short axis scan



The colour cuts in these two images are identical, demonstrating that the short axis scan has less integration time than the long axis scan (short scan has a mean of 9 counts per pixel while long scan has a mean of 5 counts per pixel.)

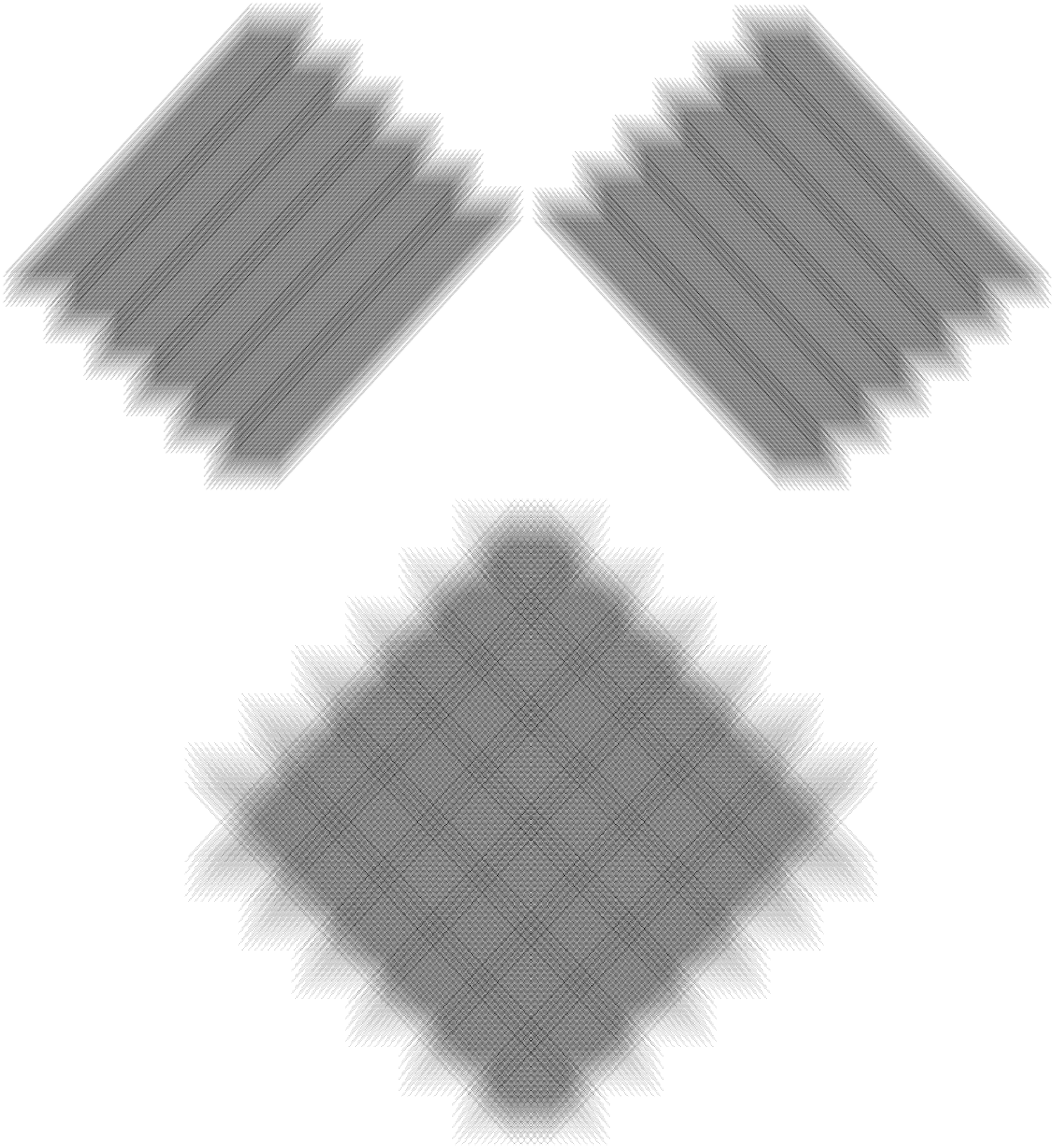
This next image shows the effect of adding one long axis scan and two short axis scans together.



The resultant map is slightly rhomboidal in shape because the two map geometries are 84.8° apart rather than 90°. This may result in the requirement to add an additional scan leg onto each map to ensure the cross area from the two scan directions covers the user stated area..

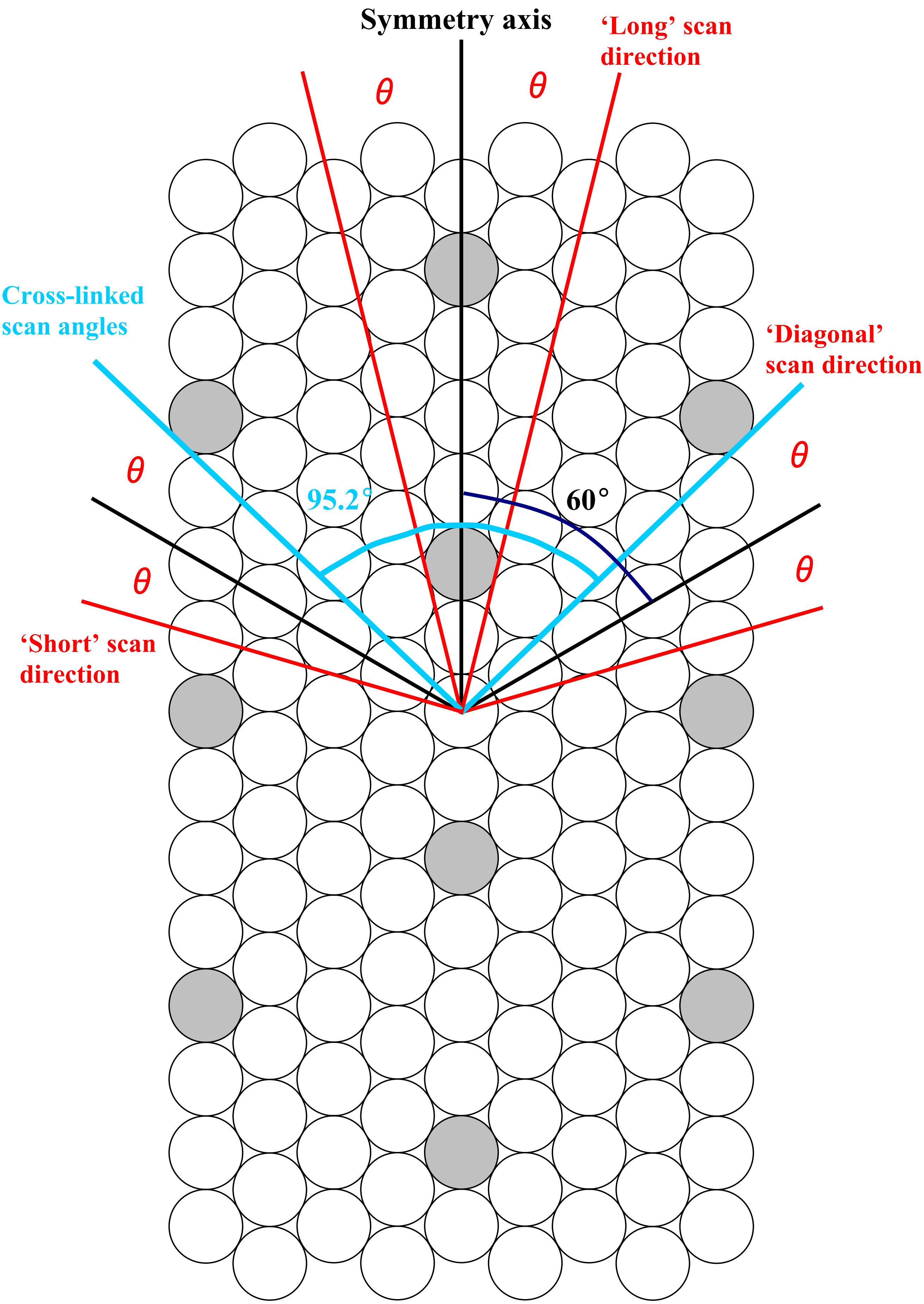
6. Alternative strategy

There is an alternative strategy for achieving cross-linked data. Rather than combining short and long axis scans, instead the two complementary diagonal scans directions are combined in such a way that the angle between them is also close to 90° (see blue scan directions in schematic 2.) The two different map geometries are then essentially identical, utilising the same step size between scan legs, and resulting in identical integration times, so equal numbers of each would be needed.



This may be a simpler option to implement.

Schematic 2. Possible alternative?



7. Notes on Map Area Calculation

The usable map area in any observation is a rather complicated function of the geometry of the SPIRE arrays and the scan pattern that's implemented. From the integration time maps shown in this note it is clear that cross-linking only adds to the complication with rhomboidal shaped maps. Let's take the instance of a single observation first and ignore the addition of cross-linked data.

Inspect the images in section 3. The green boxes give some indication of the map area that contains only data taken during the constant scan speed part of the observation and also the most uniform region in terms of integration time. The height of these boxes is roughly given by the following numbers, where n = number of scan legs:

Scan Angle	~height of map area
long	235"*(n-1)+90"
diagonal	348"*(n-1)+130"
short	455"*(n-1)+330"

The length of the green boxes is related to the length of the scan line performed at uniform scan speed. The following table summarises this distance for each scan angle, where l = total length of uniform speed scan leg in arc seconds.

Scan Angle	~length of map area
long	l-540"
diagonal	l-480"
short	l-380"

Now, this gives nice rectangular boxes but when you combine two cross-linked maps together you end up with a rhombus instead of a square. The final uniformly covered map has a size that is smaller than either of the two maps that go into making it. To ensure that the right area is covered after addition of cross-linked data it will probably be necessary to scan a larger area in the individual layers to compensate. Or plan for rhomboidal maps.

It should be noted here that because maps are created by adding scan legs together there is only so much choice in the size of maps available within an observation. This becomes especially problematic when trying to observe small areas in scan map mode. If cross-linked data is required then the absolute smallest map that can be created will be ~5.5'x5.4' (if adding a two leg long scan to a one leg short scan) but then the next biggest will be ~13.1'x13.2' (a two leg short scan plus a 4 leg long scan.) There is no possibility of making a map of intermediate size in this way. If diagonal scanning is available then a ~8'x8' map is possible by performing two cross-linked diagonal observations with two scan legs each. But then, if observers are intending to make quite small maps in scan map mode they should hopefully be aware of the implications and have a good reason for doing so.

8. References

[1] *Scan Map Scanning Angles and Separation,* Tim Waskett, Bruce Sibthorpe, SPIRE-UCF-NOT-002758