Dithering Strategy for the BTC

The problem we consider is the following: given the fact that there is a large gap between chips (of order $5'.4$), what is the best strategy to coverage as large as possible simply connected patch of sky to uniform depth?

The BTC geometry is shown on page 3 in a plot taken from the BTC User's Manual. Each chip covers a square of sidelength $14'.7$, and the gap between chips is approximately $5'.4$. In the following, we make the simplifying assumptions that the gap between the chips is constant, and that there are no relative rotations among the 4 CCDs. Neither of these assumptions are true, and the end effect will be small non-uniformities in the final coadded image.

We illustrate the exposure pattern in four stages:

1. **First pass:** Let the coordinates of the bottom left corner of chip 4 be denoted (0,0) for the first exposure. In order to cover the gap between chips 1/4, and 2/3 respectively, and provide equal and maximum overlap, perform a dither of (x,y) = (0, $10'.05$) and take an equal length exposure. Similarly, dithering by (x,y) = ($10'.05$, $10'.05$) and ($10'.05$, 0) from the original position, we cover the gaps and obtain the integration pattern shown in Figure 1. There are small squares are covered in all the integrations, while the immediately adjacent points above and beside are covered twice. The other areas are illuminted on only 1 exposure.

2. **Second pass**: The strategy is now clear: dither so that the squares that were exposed 4 times on the first pass lie on top of the squares that were exposed only once. This means do a pass around the cluster, as described above, but with the original position offset by (-$5'.025$, -$5'.025$) from the original position. The resulting exposure patter is shown in Figure 2. The central region resembles a checkerboard, with the dark squares receiving 5 total exposures, and the surrounding grey regions being exposed 4 times.

3. **Third/Fourth pass**: now to make the coverage completely uniform, we want to reproduce the checkerboard pattern in Figure 2, but offset by 1 square. To do this, do steps 1, 2 above but starting with a new original position that is offset by e.g., (-$5'.025$,0) from the original starting point. The resulting coadded image is shown in Figure 3. Over a region almost $30'$ square, the coverage is uniform.

Exposure number	x position	y position
1	0	0
2	0	$10'.05$
3	$10'.05$	$10'.05$
4	$10'.05$	0
5	$-5'.025$	$-5'.025$
6	$-5'.025$	$5'.025$
7	$5'.025$	$5'.025$
8	$5'.025$	$-5'.025$
9	$-5'.025$	0
10	$-5'.025$	$10'.05$
11	$5'.025$	$10'.05$
12	$5'.025$	0
13	$-10'.05$	$-5'.025$
14	$-10'.05$	$5'.025$
15	0	$5'.025$
16	0	$-5'.025$

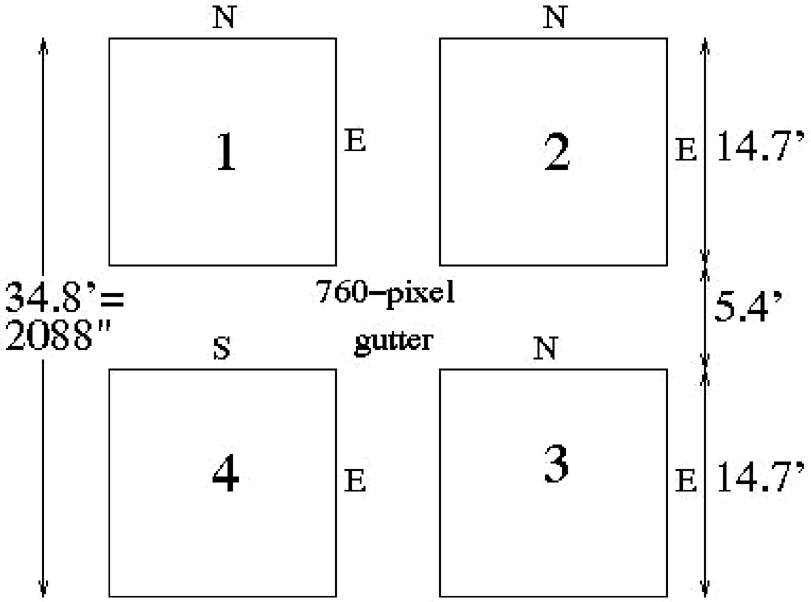
Table 1: The 16 dither exposure pattern.

The resulting coadded exposure creates a central area of $30'$ square exposed to (almost) uniform depth. Note that the seams between the squares in Figure 3 are real, created since the gap between chips $\neq 1/3$ the size of the individual chips.

Also note that this is not a highly efficient strategy. The uniform area covered only receives light on 9 of the 16 exposures. For example, taking each exposure to be 10 minutes, the entire 16 point dither is achieved in 160 minutes (not including overheads) but the uniform coverage area is only exposed for 90 minutes.

For our program, I suggest something like 15 minute individual exposures. This will give us a depth of 135 minutes, and take 4 hours to complete.

BTC Observing Tips



Approximate focus for BTC at 15.0 degrees C:

Bj	12880 = R_btc + 920	U_ctio = I_ctio + 150
R_btc	11960	B_ctio = I_ctio + 100
I_btc	11920 = R_btc - 40	V_ctio = I_ctio + 90
V_ctio	13980 = R_btc + 2020	R_ctio = I_ctio - 25

Temperature variation:

delta focus [microns] = -110*(delta T [Celsius])

To center an object on a given chip, point telescope to object coordinates modified as follows (assuming telescope has been zeroed at array center):

Chip 1: 608" E 606" S

Chip 2: 611" W 601" S

Chip 3: 603" W 603" N

Chip 4: 607" E 604" N

To move from the center of one chip to the center of another, offset as follows:

Chip 1 -> 2: 20' W
Chip 2 -> 3: 20' N
Chip 3 -> 4: 20' E
Chip 4 -> 1: 20' S

All RA offsets are in units of arc, not time. These are the units the night assistants use.

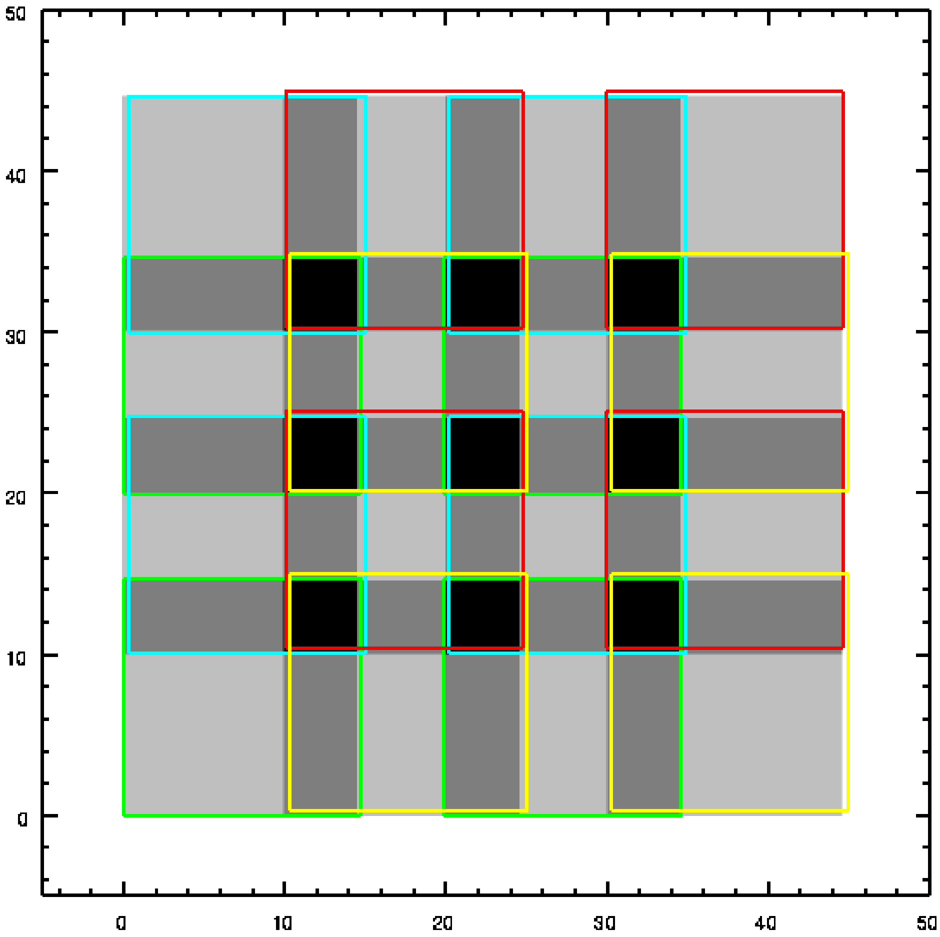


Figure 1: The first pass around the cluster. The exposures are taken at four locations: (x,y) = (0,0) with the BTC chips outlined in green, (0, 10$'$.05) in cyan, (10$'$.05, 10$'$.05) in red, and (10$'$.05, 0) in yellow. The darkest squares have received light in all four exposures. The dark grey squares are exposed twice and the lightest shaded areas only once.

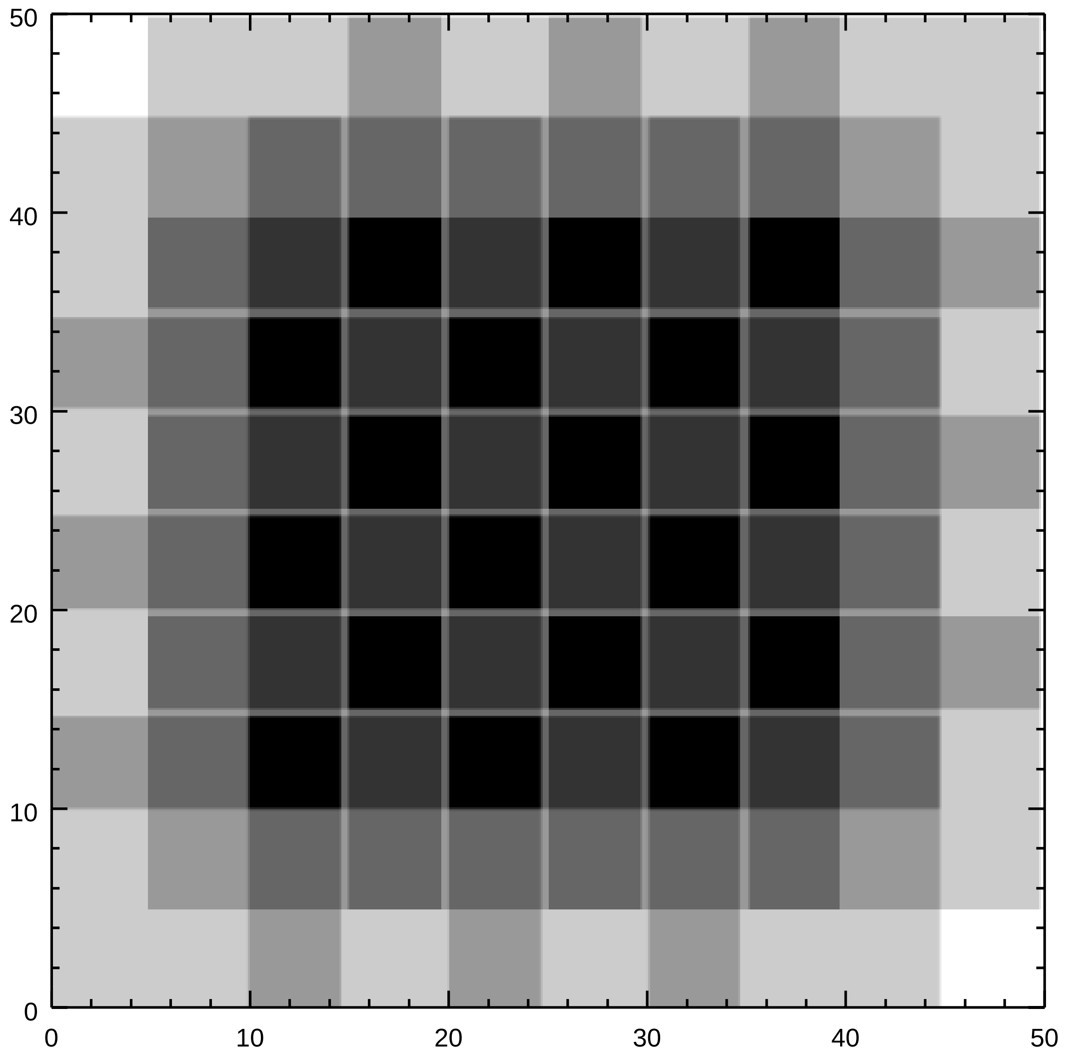


Figure 2: The sky coverage after the second pass around the cluster. We do the same pattern as in Figure 1, but with a starting position offset by (-5$'\!.$025, -5$'\!.$025) from the original position. The darkest squares have been illuminated on 5 exposures, while the next darkest have been exposed 4 times.

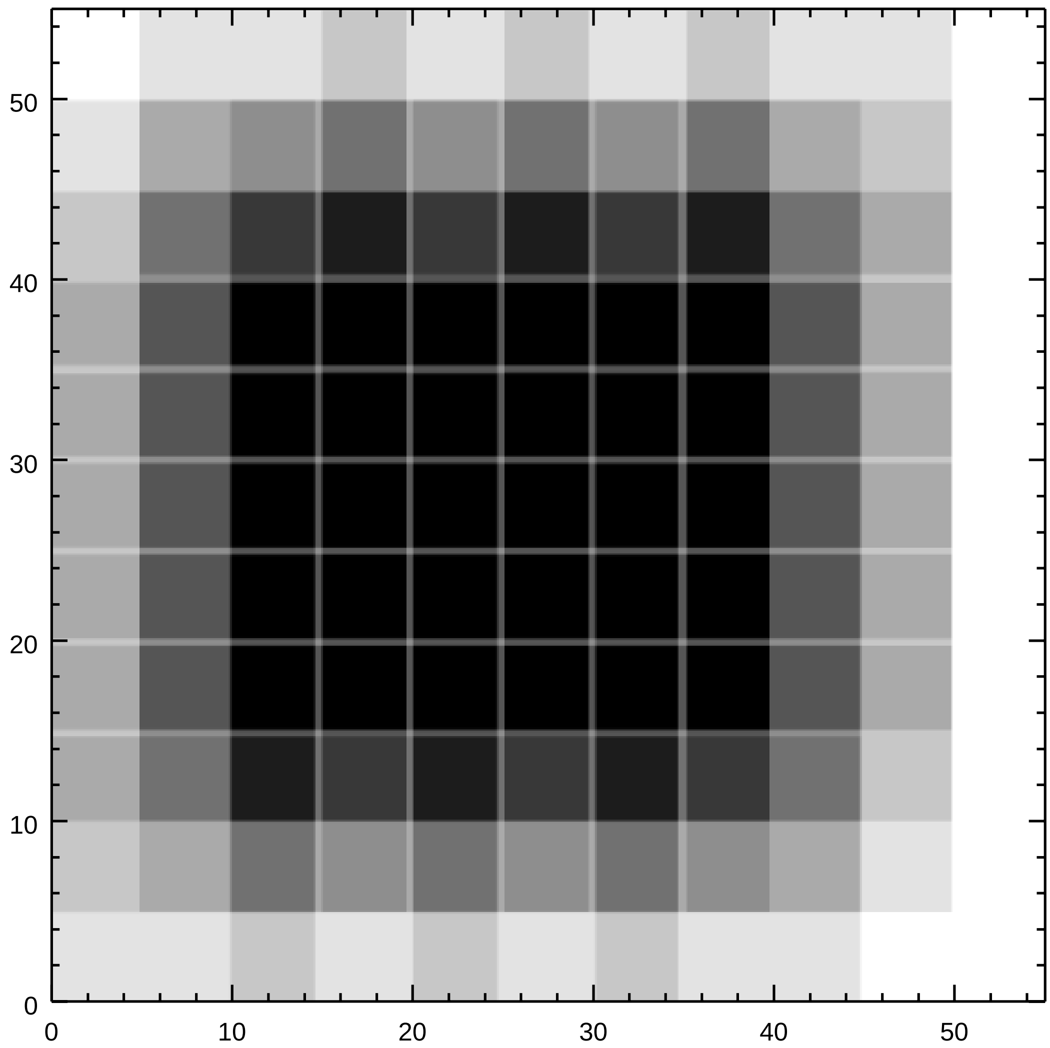


Figure 3: The sky coverage after the fourth pass around the cluster. The pattern used to create Figure 2 is repeated, now with the original starting point offset by (-5$'$.025,0) from the original exposure. The coverage is uniform over the central area of almost 30$'$ square.