ALMA Cycle 4 Configuration Combinations & Relative Integration Times
B. Mason
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1 Time Ratios

We have used the criteria described in NAASC Memo 113/ALMA Memo 598 (Mason & Brogan, 2013) to compute the relative integration times for proposed ALMA Cycle 4 array configurations (`C40-n2.tar` dated 2015-07-23 on `SCIREQ-284`). We use Eq. 17, which states:

$$\frac{t_{tot,2}}{t_{tot,1}} = \left(\frac{D_1}{D_2}\right)^2 \frac{N_{bas,1}}{N_{bas,2}} \tag{1}$$

Here $t_{tot,1}$ is the total integration time spent with array 1 for the region of interest, in general comprising a mosaic of many individual pointings of array 1; D_1 is the diameter of the antennas in Array 1; and $N_{bas,1}$ is the number of baselines which array 1 has falling within the overlap region of uv space between array 1 and array 2; and similarly for array 2. For arrays with a substantial mismatch in angular scale sensitivity between the 12-m array and the ACA, we assume an intermediate "transitional" configuration in addition. Consistent with current plans, we assume 40 12-m antennas; 10 7-m antennas; two 12-m total power antennas; and never more than two 12m configurations. We consider the following combinations: C40-1 + ACA; C40-2 + ACA; C40-1 + C40-4 ; C40-2 + C40-5 ; C40-3 + C40-6 ; C40-4 + C40-7 ; C40-5 + C40-8 ; C40-6 + C40-9. We also consider the following potential combinations: C40-3 + ACA; C40-4 + ACA; C40-3 + C40-7; and C40-4 + C40-8.

In general we take as given some required integration time for the *most extended* 12-m array, and compute the additional integration time required in more compact configurations or arrays. For the case of only two configurations (C34-2 and the ACA, for instance) this is a straightforward application of Equation 1 (Eq. 17 of the original memo). When there is a transitional configuration we do the following:

1. Compute the integration time for the transitional configuration (*i.e.*, the more compact 12-m configuration) using Eq. 1, considering the overlap region of these two 12-m configurations in uv space.

2. Compute the 7-m array integration time required to match the transitional configuration sensitivity, considering the uv range defined by the 7-m and transitional 12-m configuration overlap[1]

Results are presented in Table 1. Note that the increase in 7-m array time for the 4/1 hybrid configuration is due to the presence of the most compact 12-m array, which greatly increases the surface brightness sensitivity of the 12-m data.

Using the criteria described in the original memo we find that the total power array total integration time— *i.e.* the total time spent by *each* of the two total power dishes— is 2.0× the total 7-m array time, not counting any additional penalty due to frequency or position switching.

Other considerations in the time ratio: The analysis of S.Leon, based on integrated SNR, suggests that in cases of strongly "red" spatial structure (with power law indices of ~ 3 as seen in M51 Hα data) more moderate ratios of compact to extended array times may be used. For slightly less steep power laws, significant ratios ($> 8:1$) are still seen to be required. Another consideration is the need for good uv-coverage with the comparatively sparse 7m array, favoring longer integrations.

Important Note: For Cycle 2 and Cycle 3 observing, the time ratios actually used were a compromise fixed set of ratios $4:2:0.5:1$ (TP:7m:12m-compact:12m-extended). If there was only one 12m config, I believe the 7m:12m ratio was $2:1$ – if so this may have been a mistake caused by a misinterpretation of the specifications, it should be $4:1$ in this case. *We should make sure our intent here is clear for cycle 4.*

Suggested ratios: Implement the ratios in the table, with a maximum $t_{7m}/t_{12m,X}$ ratio of 5. Furthermore require a minimum t_{7m} integration time of 2 hours for uv-coverage reasons. We should also require the 7m, TP, and 12m array time to be called out separately in the "bottom line" time request in hours that the PI's see (the combined time request likely has biased proposers away from 7m or TP time requests).

[1] Unlike before we do not include the contribution of the more extended 12-m array to $N_{bas,12-m}$ in that range. The inclusion of the extended array baselines in the 7-m/transitional overlap region causes at most at 20% correction in the needed 7-m integration time which is in the rounding error of the time ratios likely to be implemented.

Extended (X) 12-m Configuration	Compact/Transitional 12-m cfg. (C)	$t_{12m,C}/t_{12m,X}$	$t_{7m}/t_{12m,X}$
1	-	-	11.0
2	-	-	5.44
3	-	-	1.38
4	1	0.26	2.86
5	2	0.25	1.36
6	3	0.26	0.36
7	4	0.24	-
8	5	0.29	-
9	6	0.28	-

Table 1: Relative integration times for 12-m ($t_{12m,X}$), 12-m transitional ($t_{12m,C}$), and 7-m (t_{7m}) arrays. The total power array integration time required for cycle 2 is $2 \times t_{7m}$ (see text).

2 Combinations

As a proxy for a full imaging analysis— which is desirable— I have computed the overlap properties of a variety of proposed Cycle 4 configuration. The hope is that with these metrics in hand, previous experience will allow us to select which are apropriate; to the extent this is not true more detailed simulations may be needed.

The definition currently used of the "overlap" region of two interferometer arrays is: the region of *uv* space between the *minimum* baseline of the *more extended* array and the *maximum* baselin of the *more compact* array. This can suffer from the fact that the minimum and maximum baseline may be anomalous outliers. In order to mitigate this, we also compute a "median overlap" number of baselines, defined from the cumulants of the two array configuration distributions. Let $N_>(q)$ be the *number of baselines in the more compact array with lengths greater than* q and $N_<(q)$ be *number of baselines in the more extended array with lengths less than* q. The "median overlap point" is the value q_* such that $N_>(q_*) = N_<(q_*)$, and the "median overlap baseline number" is the corresponding value of $N(q_*)$. Note that it is *not* the number of baselines in the overlap region, which is generally twice this value or a little more; but just a representative quantity.

Proposed cycle 4 configuration overlap quantities are in Table 2. My conclusions:

- All of the proposed "base" cycle 4 combinations should have reasonable imaging properties
- ACA+C40-3 is possibly usable but marginal.
- ACA+C40-4 is not usable.
- Neither C40-3+C40-7 nor C40-4+C40-8 are usable.

Configs	Overlap point	Median $N_{overlap}$ (frac.compact, frac.ext.)	Total $N_{overlap}$ compact	Total $N_{overlap}$ ext.
Cycle 2 configs				
C34-1/ C34-4	109m	207 (18%, 18.%)	1079 (96%)	426 (37.9%)
C34-2/ C34-5	162m	227 (20.2%, 20.2%)	1099 (97.8%)	628 (55.9%)
C34-3/ C34-6	238m	223 (19.8%, 19.8%)	1079 (96.0%)	612 (54.4%)
ACA-9-02/C34-1	18m	31 (42.4%, 2.7%)	45 (61.6%)	118 (10.5%)
ACA-9-02/C34-2	21m	21 (28.7%, 1.8%)	45 (61.6%)	52 (4.6%)
ACA-9-02/C34-3	30m	9 (12.3%, 0.8%)	23 (31.5%)	14 (1.2%)
Cycle 4 base configs				
c40-1n/ c40-4n	107m	207 (13.2%, 13.2%)	1555 (99.6%)	404 (25.8%)
c40-2n/ c40-5n	167m	169 (10.8%, 10.8%)	1549 (99.2%)	394 (25.2%)
c40-3n/ c40-6n	279m	165 (10.5%, 10.5%)	1559 (99.8%)	404 (25.8%)
c40-4n/ c40-7n2	456m	127 (8.1%, 8.1%)	1451 (92.9%)	344 (22.0%)
c40-5n/ c40-8n2	746m	181 (11.5%, 11.5%)	1383 (88.5%)	398 (25.4%)
c40-6n/ c40-9n2	1167m	189 (12.1%, 12.1%)	1411 (90.3%)	390 (24.9%)
ACA10/c40-1n	18m	49 (53.8%, 3.1%)	55 (60.4%)	206 (13.1%)
ACA10/c40-2n	21m	29 (31.8%, 1.8%)	55 (60.4%)	102 (6.5%)
Potential Cycle 4 configs.				
ACA10/c40-3n	24m	19 (20.8%, 1.2%)	55 (60.4%)	26 (1.6%)
ACA-10/c40-4n	30m	9 (9.8%, 0.5%)	55 (60.4%)	12 (00.7%)
c40-3n/ c40-7n2	342m	53 (3.3%, 3.3%)	1291 (82.7%)	134 (8.5%)
c40-4n/ c40-8n2	505m	79 (5.0%, 5.0%)	1091 (69.8%)	160 (10.2%)
VLA comparison				
VLA-D/C	447m	165 (23.4%, 23.4%)	673 (95.7%)	402 (57.1%)
VLA-D/B	598m	57 (8.1%, 8.1%)	499 (70.9%)	114 (16.2%)
VLA-D/A	856m	7 (0.9%, 0.9%)	103 (14.6%)	16 (2.2%)

Table 2: Comparison of array configuration overlaps. Note that the point $(-u, -v)$ is counted as a distinct "baseline" from (u, v) in the above tabulation.