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ACA Software Requirements for Cycle 1 OT

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SCOPE

This document describes the Observing Tool (OT) requirements for the ACA observations foreseen in Cycle 1.

The ACA System is designed for use as a part of the entire ALMA system in the early and full science operations phases. It is composed of an array of twelve 7-m antennas (7-m Array) and four 12-m antennas (Zero Spacing, ZS, Array). The ACA system ~~also~~ increases reliability of the interferometer maps of astronomical sources larger than the field view of the 12-m antenna. The ZS Array is capable of carrying out single-dish observations, which provide information of even lower spatial frequencies including zero-spacing data. In full science operation, a typical ACA observation is to use both 7-m and ZS Arrays as one array for calibration (typically every 200-300 sec) and to use 7-m Array (interferometer) and ZS Array (total power) as a separate subarray for observation on target. These data are combined with the data from the 12-m Array in the data processing software to make the final mosaic image of the source. In this document, we describe the available observing modes with the 7-m Array and ZS Array in Cycle 1 and indicate our suggestions for the Observing Tool (OT).

1. ACRONYMS AND DOCUMENTS

1.1. Acronyms

ACA	Atacama Compact Array
ALMA	Atacama Large Millimeter Array
WVR	Water Vapor Radiometer
OT	Observing Tool
OTF	On The Fly
SG	Science Goal
TP	Total Power
ZS	Zero Spacing

1.2. Applicable Documents

1.2.1. General Documents

1.2.2. Reference Documents

RD [1] ALMA Software Science Requirements and Use Cases for the ACA System
ALMA-70.10.00.00-008-A-SPE

RD [2] Control Software Development Plan
COMP-70.35.00.00-005-O-PLA

2. Observing Tool suggestions for Cycle 1

2.1. Scope of Cycle 1

In Cycle 1 the use of the ACA is offered, including (at least) six 7-m antennas and (a maximum of?) two 12-m antennas for single-dish observations. For single-dish observations in principle raster On The Fly (OTF) will be offered. No polarization or solar observations will be offered in Cycle 1.

2.1.1. Terminology of the different ALMA elements

This is the terminology that we will consider in this document:

• 12-m array: The array of 12-m antennas. We assume in this document a 32 element 12-m array in Cycle 1.
• ACA: The Atacama Compact Array is used in general to express the entire observing system using (twelve) 7-m antennas and (four) 12-m antennas.
• 7-m array: The array of 7-m antennas in ACA mainly operated as an interferometer. In Cycle 1 it will be composed of at least 6 ACA 7-m antennas. Cross-correlation is processed with the ACA Correlator and atmospheric phase calibration for the ACA is conventional without WVR. As options, we do not rule out using the water vapor radiometers on the ZS Array. In that case, the calibration shall be determined from the phase plane using the water vapor radiometer measurements, and apply it to not only the TP Array but also, by interpolation, to the ACA 7-m Array. The 7-m will be distributed only in a compact configuration in Cycle 1.
• *TP array*: The 12-m ACA antennas, with (a maximum of?) 2 antennas in Cycle 1, mainly operated as single-dish telescopes. The standard observing modes for the ZS array shall include auto-correlation spectral line mapping with raster On The Fly (OTF). Note that nutator and frequencies switching capabilities are beyond the scope of Cycle 1.

We assume OTF interferometry is not commissioned, so we only have available pointed mosaics for the 12-m and 7-m arrays.

2.1.2. Observing modes

The observing modes available in Cycle 1 will be the following:

1) 12-m array
2) *12-m array + 7-m array,*
3) 12m array + 7-m array + ZS array (single-dish observation)

The 12-m array, 7-m array and ZS array are in general used separately (except time critical observations where both 12-m array and ACA need to be observed in a coordinated way). The 12-m array will use 64-antenna Correlator, while the 7-m and ZS Arrays (ACA), the ACA

Correlator. It is not offered in Cycle 1 standalone observations of either the 7-m and/or the ZS Arrays.

2.2. Proposal and Observation preparation using the Observing Tool (OT)

We aim to minimize the amount of variables needed as inputs. A single science goal (SG) will be entered for the 12-m array, and from this the ACA inputs will be automatically determined. Observations with each element (12-m, 7-m and ZP Arrays) will be performed with independent scheduling blocks created in Phase 2.

We split the OT requirements in Phase 1 and 2, and classify them according to field, spectral, calibration, and control and performance setups.

2.2.1. Phase 1

Field setup

[Req-Phase1-001]In a science goal, the OT assumes that the fields to be observed by 12-m, 7-m and ZS Arrays are the same. Once user specifies the mapping area for the 12-m array, the mapping area with the 7-m and TP Arrays will be calculated by OT automatically. ZS mapping area: If single field area is larger than field of view (FoV) of the ZS antenna then add 0.5 of a 12-m beam on each side of the map used for the 12-m mosaic. For 7-m antenna use the same area as the 12-m map. Note of course that there will be fewer pointings because of the larger beam. Nyquist sampling is not mandatory for the 12-m or 7-m arrays, but the TP map really **needs** it (even if user has specified an under-sampled map interferometry!). See in Figure below the current spatial visual editor in OT currently under development.

[Req-Phase1-002]In principle only “square" patterns allowed - but need to check with Control if other patterns are available.

[Req-Phase1-003]Display pointings for the 7-m and ZS Arrays (with beams also overplotted). For a given science goal do not allow modifications in the 7m and TP array area to be mapped.

[Req-Phase1-004]Add information on the field of view of the 7-m antennas (now only 12-m).

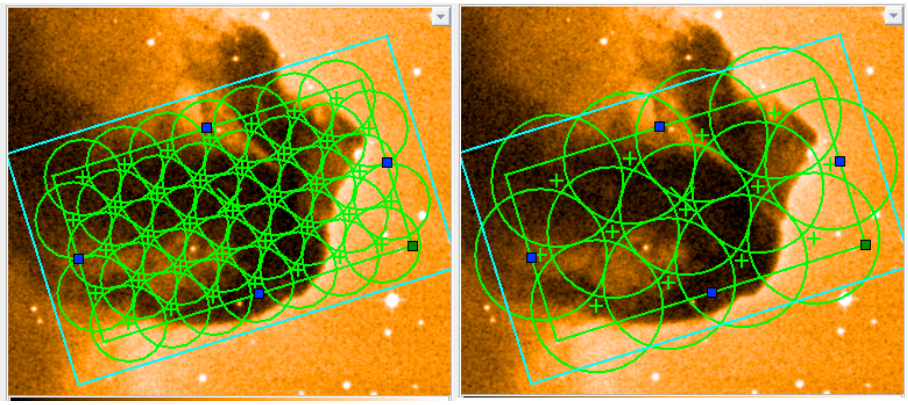

Figure. Left) Rectangles showing the 12m (green) and Total Power (blue) fields to be observed. Circles show the different pointings (and beam widths) of the 12m-array. Right) Same but for the 7m-array.

Spectral setup

[Req-Phase1-005]Spectral setting for the 64-antenna Correlator (12-m array) and ACA Correlator (7-m array and/or TP array) should be in general the same. The designs of the correlators are different (FX and XF, respectively), and consequently their resulting frequency response patterns are also different. But there is no action item to do in the OT to absorb this difference in Cycle 1.

Calibration setup

[Req-Phase1-006]Same as for the 12-m Array, but including 'Goal Calibrators' for the 7-m Array (user-defined calibration, which might be in principle different to that of the 12-m Array). For the ZS Array a number of different parameters would be needed. For example, the OFF position, but these can be specified in Phase II.

Control and Performance

[Req-Phase1-007]Add suggestion to the proposer to use ACA by using simple criteria (without a simulator). OT shall suggest a proper combination (12-m array and 7-m array or 12-m array, 7-m array and TP array) to achieve the largest angular scale indicated in the SG (We assume that the configuration of the 12-m Array is determined by the spatial resolution.)

[Req-Phase1-008]The observing time ratios between ACA (7-m and ZS Arrays) and 12-m Arrays have been estimated for different configurations of the 12-m Array (see Table below) based on uv plane densities and image simulations. User defined input is not allowed in general.

ALMA-12m configulation (No.)	32-1	32-2	32-3	32-4	32-5
Relative On-Source time of ACA-7m to ALMA-12m arrays	***5(TBD)***	***3(TBD)***	***2(TBD)***	***1.3(TBD)***	***1(TBD)***
Relative On-Source time of TP-12m to ALMA-12m arrays	***5(TBD)***	***3(TBD)***	***2(TBD)***	***1.3(TBD)***	***1(TBD)***

The combination of ACA and more extended configurations than "32-5" in the ALMA 12-m array will not be offered in general because uv-coverage in those cases are very poor. We have excluded the combination of 12-m array and ZS array because the image performance is of difficult quantitative evaluation. ***Also, note that the ratios above are still under discussion.***

[Req-Phase1-009]The numbers of 7-m and ZS antennas are still to be determined. The numbers of the 7-m and 12-m antennas need to be a variable that can be modified, as it is now in the sensitivity calculator.

[Req-Phase1-010]Accounting for extra calibration time is required in the calculation of ACA observing time. This depends on the observing mode used (see S 2.2.3). Time should be added due to slewing to the OFF position in ZS observations.

<Suggestion>

- Signal to noise ratio difference among 12-m, 7-m, and ZS arrays can be roughly estimated from peak flux density and source size and properly suggested by OT.
- The total observing time shall be the sum of that required by each array (12m, 7m and ZS Arrays).

2.2.2. Phase 2

Field setup

[Req-Phase2-001]Modifications in the field setup for the three ALMA elements (12-m, 7-m and ZS Arrays) would be available in Phase 2?

Spectral setup

[Req-Phase2-002]Show spectral setting for ACA Correlator and allow to modify (?). In principle the conversion of the frequency response pattern should be done offline.

Observation strategy and Calibration

[Req-Phase2-003]Define different calibrators and observing times, cycle times, etc. for

each array.

[Req-Phase2-004]All the parameters regarding OTF automatically set as recommended by JAO, including Scanning Speed, Spatial Sampling and OFF position (anything else?). The OFF-position needs to be defined with the input from the user.

[Req-Phase2-005]In general, observations are carried out independently in each element of the ACA.

2.2.3. Stages of ACA observing modes in Cycle 1

The ACA observing mode capabilities will likely evolve during Cycle 1, enhancing its efficiency. In chronological order we foresee the following steps:

A. Observations with the 7-m and ZS Arrays are carried out *independently* using the ACA Correlator. This is the simplest case and in general the most suitable for Cycle 1.

B. Observations with the 7-m and ZS Arrays are carried out *simultaneously using the 'subarray'* capability for ACA Correlator. However, verification of this mode is still needed in CSV activities.

In both cases, two scheduling blocks are necessary for the 7-m and ZS Arrays, respectively. The other observing modes (for example switching from the full-array to subarray modes using only one scheduling block) are not offered in Cycle 1.