Additional 12m Antennas for ALMA

In the **ALMA Scientific Specifications and Requirements (ALMA-90.00.00.00-001-A- SPE)** requirement SCI-90.00.00.00-100-00 states that ALMA shall be comprised of 64 12-m antennas. In that document, this number of antennas is derived from the Level One Science Requirements as set forth in Annex B of the Bilateral Agreement. Each of the two bilateral partners signed a contract in 2005 each for the construction of 25 to 32 12m antennas. Following the rebaselining of ALMA, current plans call for the delivery of 25 12m antennas from each of the two contracts. Options for construction of additional antennas at fixed cost expire in summer 2009. In the interim, NINS (Japan) has joined ALMA, signing a contract for an additional four 12m antennas as well as twelve 7m antennas, to be sited in an Atacama Compact Array (ACA) and tasked with providing the wider field data needed to ensure that ALMA imaging meets its challenging goals. In this short paper we address the need for additional 12m antennas to be purchased under the options in the bilateral contracts.

Additional antennas restore capability to ALMA in two fundamental areas: (1) the sensitivity of the array is increased, and (2) the imaging capability of the array is improved. These two areas have been discussed by the ALMA Science IPT (1,2), the ALMA Scientific Advisory Committee (3,4,5) and by a committee appointed by the US National Research Council (6). Since most of these reports (1 and 3-6) were issued, the enhancement of ALMA by the addition of the ACA has improved the first of these areas somewhat. As the 64-element correlator has excess capability for the 12m Array of fifty antennas, a means of patching ACA antennas into the correlator has been implemented to the 64-input limit of its capacity. The additional collecting area provided by the 16 ACA antennas is the equivalent of an increase in collecting area of about 15%, or nearly eight 12m antennas (2). The entire complement of 66 antennas cannot be patched into the 64 station correlator. Furthermore, all antennas are unlikely to be available at one time—in reference (6) it was assumed that a 50 antenna array would require the construction of 54 12m antennas, rather than of the 50 currently contracted. Most of the 64-antenna array calculations assumed a 60 antenna operational array, taking into account the fact that antenna availability would seldom reach 100%. Assuming that this would also hold true for a combined array, we assume 46-48 12m antennas from the bilateral array could be available. We calculate that the collecting area of a combined array would be 90-94% that of a sixty 12m antenna ALMA; a given integration could take 19%-13% longer than with the full specified complement of operational antennas.

The imaging capability of the array is improved by the addition of the ACA antennas in the case of low resolution images (2), but not for very high resolution images (1,6), as needed to satisfy the second and third elements of the Level One ALMA Science Goals. For very high resolution images, 0.1" or better at 850 microns, baselines on the order of 2km are needed; baselines which can only be provided by configurations of the 12m Array. For high resolution images, fewer than 50 antennas may be available in the operational ALMA. Two conclusions of the NRC committee were that (a) the Level One goal of high-contrast imaging of protostellar disks could not be met by an array of 50 operational antennas and (b) that image fidelity would be degraded by a factor of two with such an array. These conclusions are supported by study (1), which showed that imaging capability dropped rapidly as number of antennas dropped below ~56. As the contracted complement of 12m antennas for ALMA is 50, the operationally available number of antennas could be 46-48, impacting ALMA's ability to provide excellent high resolution images.

The science capabilities of ALMA, while transformational, are limited by the current 50 antenna scope of the bilateral array. High resolution imaging is most at risk as confirmed by a number of studies. An additional 4-6 12m antennas added to the current 50 antenna complement of the 12m Array would:

- Increase sensitivity for the combined array by 5-7%[1], and for the 12m Array by 8-13%, decreasing integration time by 17-27% (2)
- Increase high resolution imaging quality by as much as a factor of two in image fidelity (1,6)

References

(1) Image Quality as a Function of the Number of Antennas in ALMA. M.A. Holdaway (2005)
(2) On the Scientific Benefits of Cross Correlating the 12m Array and the ACA Daisuke Iono, Shigehisa Takakuwa, Ryohei Kawabe and B. Vila Vilaro (ALMA-J Office) (2007)
(3) ASAC Report September 2004
(4) ASAC Report February 2005
(5) ASAC Report October 2004
(6) ***The Atacama Large Millimeter Array (ALMA): Implications of a Potential Descope*** issued by the US Committee on Astronomy and Astrophysics (CAA) Board on Physics and Astronomy (BPA) Space Studies Board (SSB) (2005)

[1] In the low resolution but high sensitivity combined array, 12m antennas can replace 7m antennas in the 64 available correlator slots. In the 12m Array, additional antennas occupy vacant slots.