Even longer baselines: feasibility and observational implications

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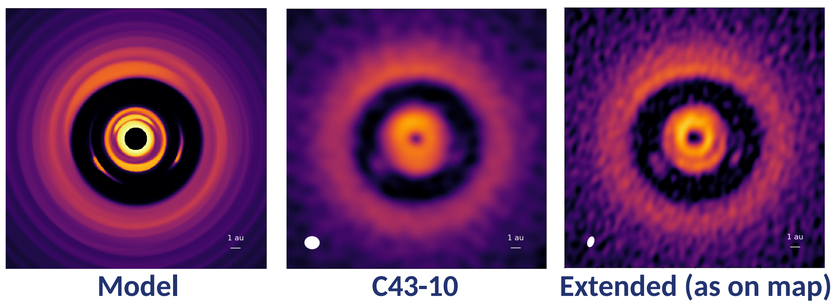
Abstract: ALMA's high spatial resolution capabilities, provided by baselines of up to 16km length, have revolutionised observational millimetre/sub-millimetre astronomy. Although challenging in many respects, observations with the longest construction baselines have been highly successful. Offering even longer baselines is an obvious axis for development of ALMA, but what are the possibilities for achieving this, and what implications would there be on scientific observations? Here is presented a brief status overview of an ongoing ALMA development study investigating a simple baseline extension within the current operational model and with minimal technological changes. Recent test campaigns of interferometry between antennas at AOS and OSF sites (a 24km baseline with 2.2km altitude difference) have been performed with promising results, opening this up as a testbed for long baseline calibration techniques in addition to working towards demonstrating feasibility of a real array extension for general scientific imaging in future.

Science cases

A more extended array will particularly lend itself to lower frequency observations, up to Band 6/7, allowing to match the resolution of high frequency observations with existing configurations. For protoplanetary discs it will allow imaging dust at longer wavelengths, where dense regions such as sites of planet formation are less optically thick. Science cases with bright compact emission (for self-cal) such as evolved stars (photospheres, ionized winds, masers etc.) and quasars could also occasionally use high frequency bands to achieve ~5mas resolution.

Protoplanetary disc simulation (345GHz, 8h track, -24° Dec)
Courtesy of Luca Ricci & John Carpenter



Model | C43-10 | Extended (as on map)

Test campaigns

- **April 2012:** Previous brief tests of connecting antennas over AOS-OSF communication fibers, including quick interferometry test without delay tracking (Olguin et al. 2012, SPIE, 8452, 84522A)
- **Oct 2018:** 2 antennas at AOS connected to LO and correlator at OSF for extensive tests of connectivity (receiver locking, time synchronisation and digital transmission); very successful, including interferometric observations working as normal
- **June 2019:** an AOS and an OSF antenna connected to LO and correlator at OSF for **long baseline interferometry testing (24km baseline)**; included tests of modified Digitiser Clock (DGCK) firmware and control software to support 1.5x higher delay rates; stations were properly integrated for normal observing; several nights of interferometry observations were made; analysis ongoing.
- **Future**: further single long baseline tests (TBD); correlator delay rate stress testing for many antennas; eventually tests with OSF antennas connected in main array with many AOS antennas.

Station locations and array size

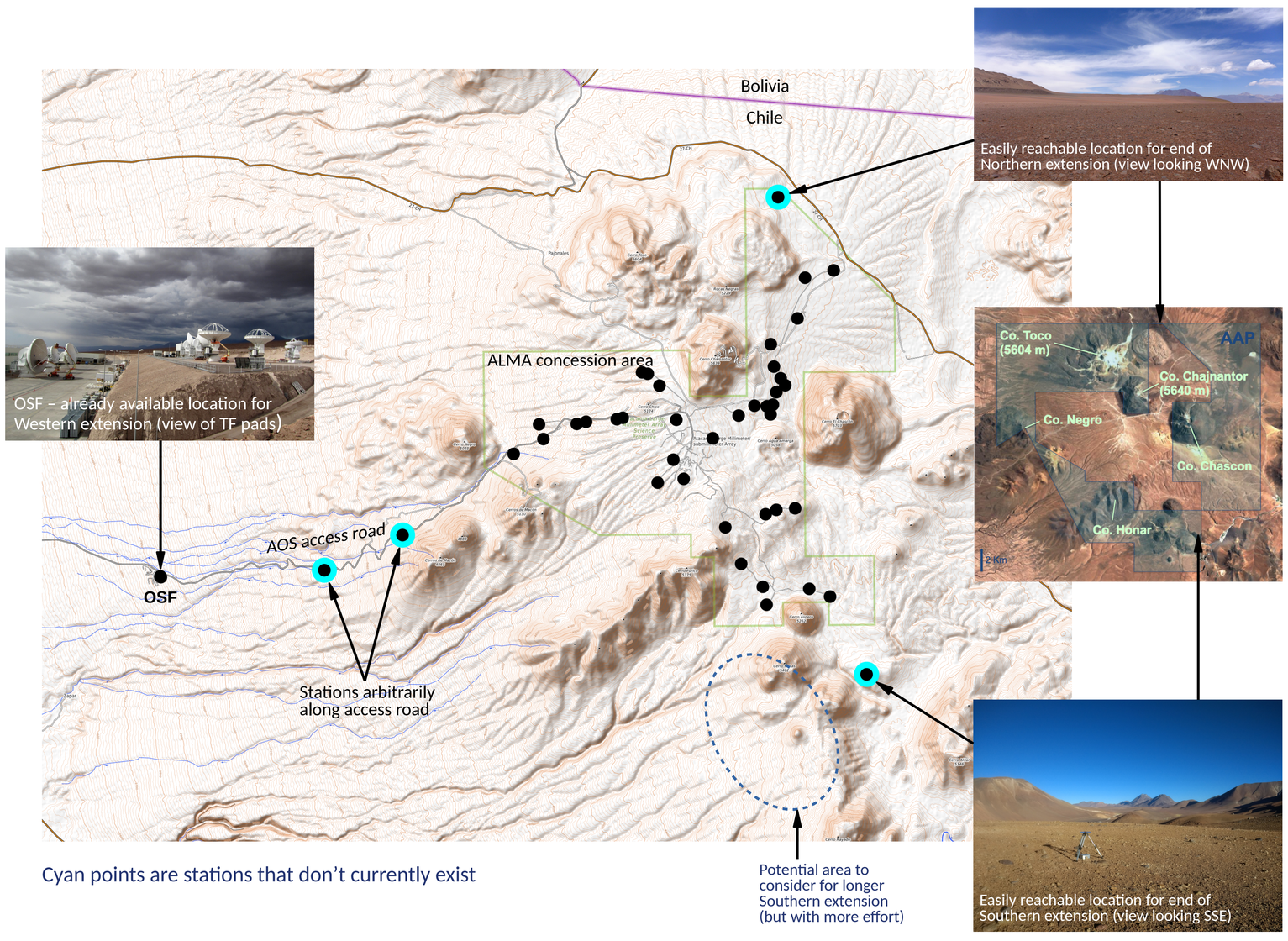
This study considers specifically additional stations which could be reached by antenna transporter (i.e. by wide, low gradient roads), and connected like existing stations for power and communication, i.e. stations that would fall under the current operating model of ALMA. Also considered are practical boundaries of existing land concessions and public roads.

Extending current branches (refer to map below):

- **West**: Use existing OSF stations (2900m altitude) and add stations along the AOS access road
- **North (Pampa la Bola)**: 4km extension possible within the existing ALMA concession; any further would likely be difficult due to crossing a public road and proximity to the Bolivian border
- **South**: Extension requires going outside the ALMA concession, but can be within the surrounding Atacama Astronomical Park (AAP); there is an easily reachable location 4km to the SSE which is prime candidate; an area further South, still within the AAP but likely more difficult (expensive) to reach also warrants investigation.

Operation would likely be in a campaign mode, making use of all antennas (~55-60 typically at any time), and long full-track observations to maximise surface brightness sensitivity and *uv* coverage.

Map indicating existing most remote stations plus some representative new ones



Cyan points are stations that don't currently exist

Summary: Extensive interferometric observations were successfully made with a single 24km baseline between AOS and OSF sites in June 2019. Previous missions tested the technical feasibility of connection. Delay tracking was successfully tested up to delay rates corresponding to worst case for 20km distance from the array centre. A lot of observational data was taken and is under analysis. After the single baseline is fully demonstrated, test campaigns performing interferometry with OSF antennas together with many antennas at AOS will provide the final technical feasibility test for an array size extension by a factor of ~2. Such an extended array would especially increase the spatial resolution achievable at lower frequencies (as little observing time would be possible for high frequencies). Please ask for further info as there's not space for much on a poster!