Simulating fast on-the-fly observations of the Sun with AtLAST

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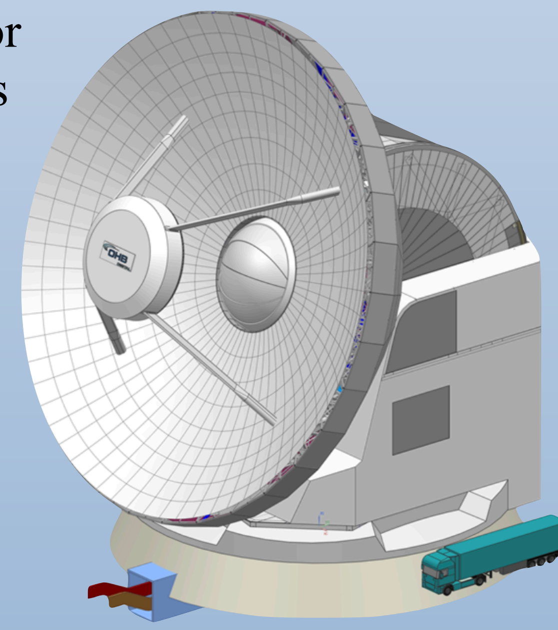
Abstract

The Atacama Large Aperture Submillimeter Telescope (AtLAST), a proposed 50m single-dish millimetre telescope to be built in the Atacama Desert, could lead to interesting new discoveries in the field of solar millimetre astronomy. AtLAST's proposed frequency range from ~30 GHz to 1 THz would mainly observe solar continuum radiation originating in the chromosphere. However, the chromosphere's highly dynamic nature prohibits meaningful observations to have long integration and scan times, therefore requiring the utilisation of fast on-the-fly scanning techniques. Such techniques are already used by facilities such as the Atacama Large Millimeter/submillimeter Array (ALMA), completing a scan of the full solar disk in ~ 10 minutes[1,2]. A large multi-pixel detector at AtLAST could reduce the required scan time considerably. By utilising the maria code[3] we explore how different instrumental properties, scanning strategies and detector counts affect the full-disk observations and the required scan times.

Atacama Large Aperture Submillimeter Telescope (AtLAST)

AtLAST is a proposed next-generation (sub-)mm single-dish telescope with a planned 50-m aperture. Its proposed 2° maximal field of view (FoV) and 3° s^{-1} scan speed would make it an excellent facility for mapping the mm-sky, and a solar observing mode is also being planned[5].

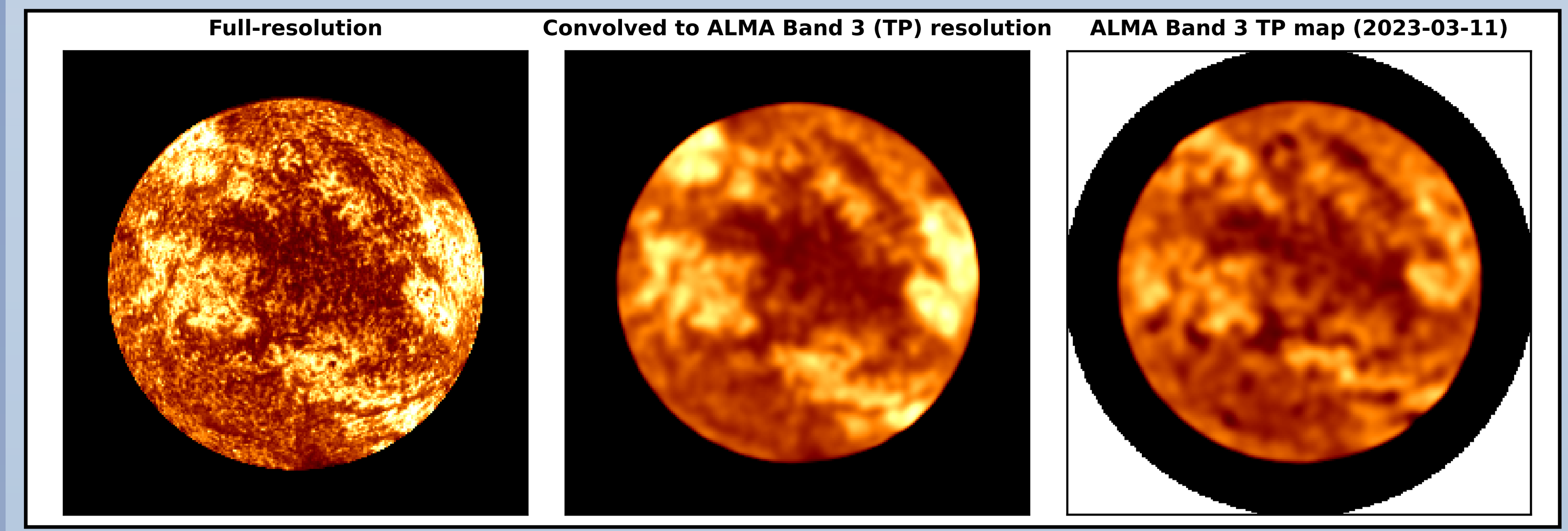
Its large maximal FoV in combination with multi-pixel detectors would make AtLAST a useful tool for mapping solar mm-radiation in different frequency bands at sufficiently high resolution and on short time scales.



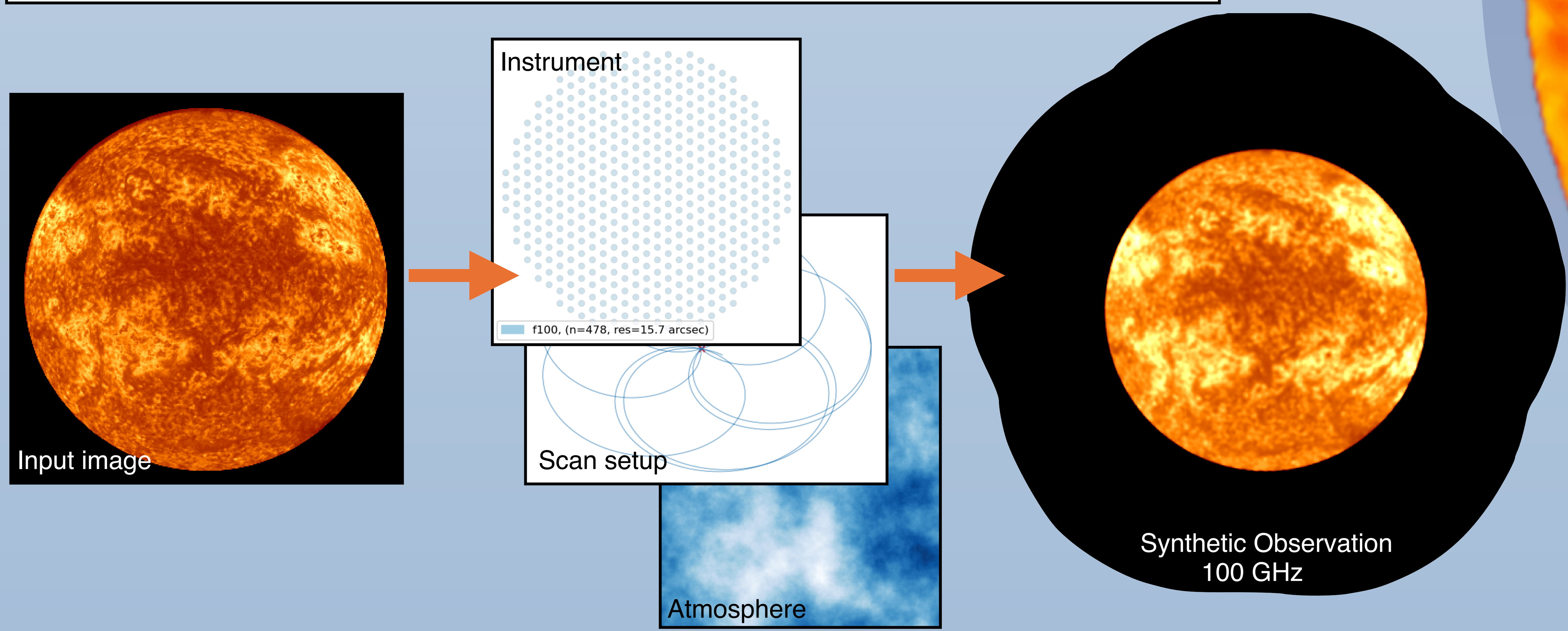
Mroczkowski et al. (2024)

Simulating solar observations with `maria`

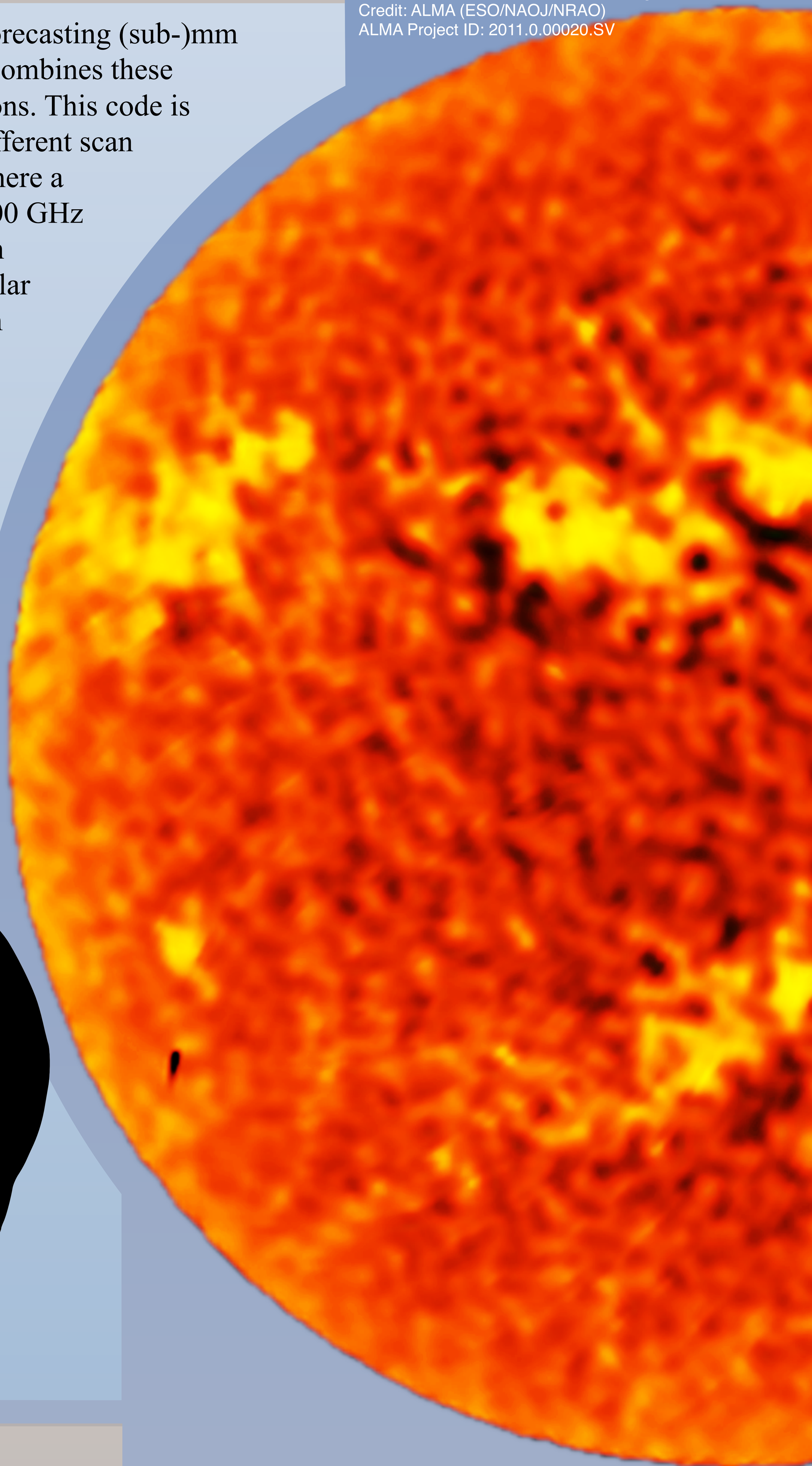
Synthetic AtLAST observations of the solar disk are created using maria[3], a single dish telescope simulator made for forecasting (sub-)mm observations and a powerful tool for exploring different instrument designs and scanning strategies. The maria code combines these instruments and scanning strategies with a highly realistic generated atmosphere to create synthetic AtLAST observations. This code is utilised to explore how different instrument designs, spacing, and number of detector elements, in combination with different scan patterns affect the synthetic observations, and the time required to fully sample it. Such an example is shown below, where a relatively small instrument of 478 pixels following a double-circle pattern. This scan fully sampled the whole Sun at 100 GHz (comparable to ALMA Band 3) in ~25 seconds. The synthetic observation also highlights the considerable difference in resolution between AtLAST and an ALMA TP antenna. The input image used is constructed from UV data from the Solar Dynamics Observatory (SDO), and made to resemble real ALMA data as closely as possible. The input image is shown below, both at full resolution and convolved to ALMA Band 3 resolution.



ALMA Project ID: 2022.1.01544.S



Below: A full-disk map of the Sun at 1.25 mm (Band 6) made using one of ALMA's Total Power (TP) antennas. These maps are complementary to the higher resolution interferometric observations of small regions with ALMA.
Credit: ALMA (ESO/NAOJ/NRAO)
ALMA Project ID: 2011.0.00020.SV



Preliminary results

We simulated a possible first-generation solar instrument for AtLAST consisting of 50000 detector elements configured in a filled circle. These pixels were multi-chroic, and could observe in four frequency bands simultaneously. We centred the four bands on 100, 300, 500, and 700 GHz. This resulted in an instrument with a instantaneous FoV of ~0.147°, big enough to instantaneously cover active regions, but also for scanning the full disk at short time scales. We find that such an instrument could be used to scan the full disk in ~18.5 seconds, even at 700 GHz, a time-scale that is not possible with any current millimetre facilities. If such an instrument would be built for AtLAST, it would give us an unprecedented view of the millimetre Sun, making it possible to map the solar chromosphere in three dimensions through simultaneous multi-frequency maps. Its high cadence would also greatly aid in future detections of flares at millimetre wavelengths.

References

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