

Fast Single-Dish Scans of the Sun Using ALMA

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Abstract. We have implemented control and data-taking software that makes it possible to scan the beams of individual ALMA antennas to perform quite complex patterns while recording the signals at high rates. We conducted test observations of the Sun in September and December, 2014. The data returned have excellent quality; in particular they allow us to characterize the noise and signal fluctuations present in this kind of observation. The fast-scan experiments included both Lissajous patterns covering rectangular areas, and “double-circle” patterns of the whole disk of the Sun and smaller repeated maps of specific disk-shaped targets. With the latter we find that we can achieve roughly Nyquist sampling of the Band 6 (230 GHz) beam in 60 s over a region 300'' in diameter. These maps show a peak-to-peak brightness-temperature range of up to 1000 K, while the time-series variability at any given point appears to be of order 0.5% RMS over times of a few minutes. We thus expect to be able to separate the noise contributions due to transparency fluctuations from variations in the Sun itself. Such timeseries have many advantages, in spite of the non-interferometric observations. In particular such data should make it possible to observe microflares in active regions and nanoflares in any part of the solar disk and low corona.

The ALMA dishes permit solar data to be obtained on the fly, as an antenna executes a smooth but quite rapid motion. Precise tracking corrections allow the antennas to be driven at frequencies of order 1 Hz, with excellent SNR at sampling times of msec. Area scanning with a pencil beam, for example with a Lissajous pattern, has a long heritage in radio astronomy (e.g. Kovács 2008). A Lissajous drive generally concentrates the coverage on the boundaries of a rectangular area; we have also used “double circle” drive patterns, the sum of large and small drive circular functions (Figure 1 shows a double-circle pattern with the functions in a 2:1 amplitude ratio). These have the merit of frequent return to the pattern center, thus providing relatively high-frequency sampling of the same part of the Sun. Since the solar image varies only slowly, outside of flares, this capability acts as a guide to the system’s radiometric stability of the entire pattern at a frequency of order 1 Hz. This in some measure replaces chopping for this purpose. The fast scanning of a small area, centered on an active region is an excellent way to achieve mapping observations with high time resolution over an area larger than the beam width. Given the stability of the observations (see below) this will enable ALMA to probe radiometric parameter space far better than any previous system, even with the use of just a single dish: such data will yield definitive observations of microflares and nanoflares (e.g., Hudson 1991).

Figure 2 shows maps made from large and small double-circle scans with a single dish (PM01) at the ALMA low site during tests in September 2014).

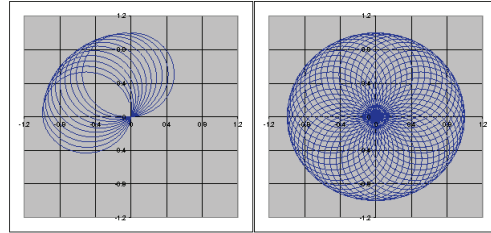


Figure 1. A double-circle scan pattern (left, just beginning; right, completed) composed of 2:1 amplitude ratio and fast scanning on the small circle.

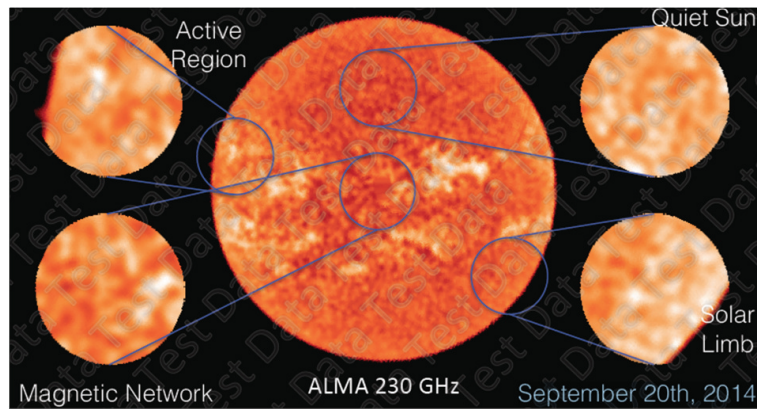


Figure 2. Test images from the September 2014 campaign, using double-circle scanning over the whole Sun and four sub-regions. The wisps above the solar limb (upper left small image) are real solar features.

The structure on arcmin scales seen in all five of the images in Figure 2 reflects the presence of the chromospheric network, which the ALMA test data show to be highly reproducible on 60-s image cadences. This hints at the unprecedented accuracy and precision we believe ALMA will bring to basic subjects such as limb brightening.

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References

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