Living Around Active Stars
Proceedings IAU Symposium No. 328, 2016
D. Nandy, A. Valio & P. Petit, eds.

doi:10.1017/S1743921317004148

Solar Radius at Sub-Terahertz Frequencies

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Abstract. The visible surface of the Sun, or photosphere, is defined as the solar radius in the optical spectrum range located at 696,000 km (Cox *et al.* (Ed. 2015)). However, as the altitude increases, the dominant electromagnetic radiation is emitted at other frequencies. Our aim is to measure the solar radius at frequencies of 212 GHz and 405 GHz through out a solar cycle and, therefore, the altitude where these emissions are generated and that variation along the years. Also we tried to verify the the radius dependence on the solar activity cycle, which can be a good indicator of the changes that occur in the atmosphere structure. For this, we used data obtained by the Submillimetric Solar Telescope (SST) created from daily scans made by SST from 1990 to 2015. From these scans a 2D map of the solar disk was constructed. The solar radius is then determined by adjusting a circumference to the points where the brightness is half of the quiet Sun level, which is set as the most common temperature value in the solar map, *i.e.*, the mode of the temperature distribution. Thus, we determined the solar radius at 212 and 405 GHz and the altitude of the emissions respectively. For 212 GHz, we obtained a radius of 976.5"±8" (707±4 Mm), whereas for 405 GHz, we obtained 975.0"±8" (707±5 Mm). optical spectrum range

Keywords. Sun: activity, Sun: chromosphere, Sun: fundamental parameters, Sun: radio radiation

1. Introduction

The Sun is considered a mildly active star with an 11-year activity cycle. It emits radiation across the electromagnetic spectrum at several wavelengths, from gamma rays to radio waves.

Our aim is to measure the solar radius at frequencies of 212 GHz and 405 GHz and, therefore, the altitude where these emissions are generated. The relevance of this research is the possibility to understand more about the solar atmosphere and what is the radius dependence on the solar activity cycle, which can be a good indicator of the changes that occur in the atmosphere structure.

2. Sub-terahertz observations

We used data obtained by the Submillimetric Solar Telescope (SST), in the Astronomical Complex El Leoncito Observatory (CASLEO) at the Argentinean Andes in partnership with the Center for Radio-Astronomy and Astrophysics Mackenzie (CRAAM). This telescope uses a multibeam system operating at radio frequencies with 4 beams at 212 GHz and 2 beams at 405 GHz (Figure 1a). Maps of the whole Sun were created (Figure 1b) from daily scans made by SST from 1999 to 2015 (Figure 2).

The the quiet Sun level is set as the most common temperature value in the solar map, i.e., the mode of the temperature distribution (Figure 3a). Next, the solar limb is set as the half of the quiet Sun level (Figure 3b). Then, the solar radius is obtained by

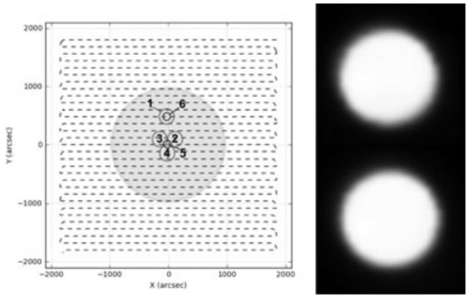

Figure 1. Left: scans over the solar disk made by SST. The colored circles represent the telescope beams. Right: examples of solar maps made from SST's data.

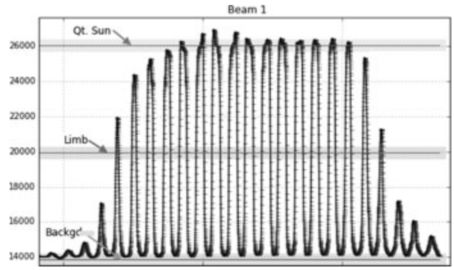

Figure 2. Solar intensity as a function of time during the scan map from SST-beam 1 at 15 UT on 23 February 2012 showing background and quiet Sun values.

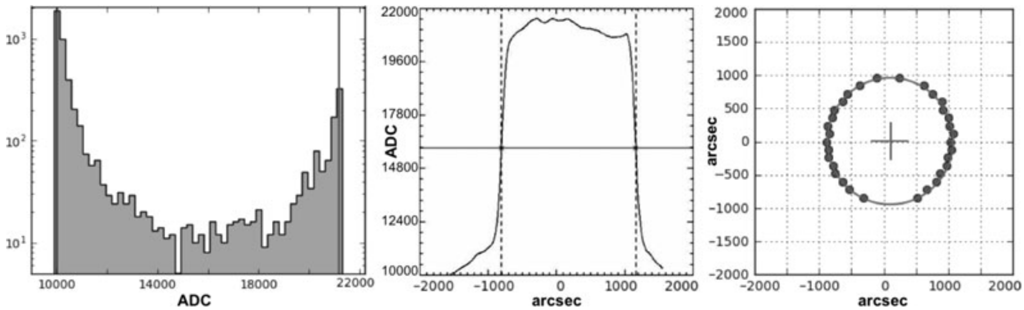

Figure 3. Left: histogram of intensities where we define the value of quiet Sun. Middle: the markup of the limb points. Right: the coordinates of the limb with the circumference fit.

Table 1. Solar radius results for 212GHz and 405GHz frequencies

Frequency	Radius (arcsec)	Radius (Mm)	Altitude (km)
212 GHz	974 ± 5	707 ± 4	11,492
405 GHz	974 ± 7	707 ± 5	11,492
Optical	959.63	695.508 ± 0.026	0

adjusting a circumference to the solar limb points (Figure 3c). Thus, by substracting the sub-THz radius from the visible one, we are able to determine the altitudes where the 212 Ghz and 405 GHz emissions are generated.

3. Preliminary results

For 212 GHz, we obtained a radius of 974"±5" (707±4 Mm), whereas for 405 GHz, we obtained a radius of 974"±7" (707±5 Mm). These results are shown in Table 1 and Figure 4.

In addition to the mean solar radius results at both frequencies, we investigated the relationship of the solar radius variation at submillimetric wavelengths with the solar activity cycle of 11 years. Unfortunately it was not possible to observe this relationship due to high dispersion of data.

https://doi.org/10.1017/S1743921317004148 Published online by Cambridge University Press

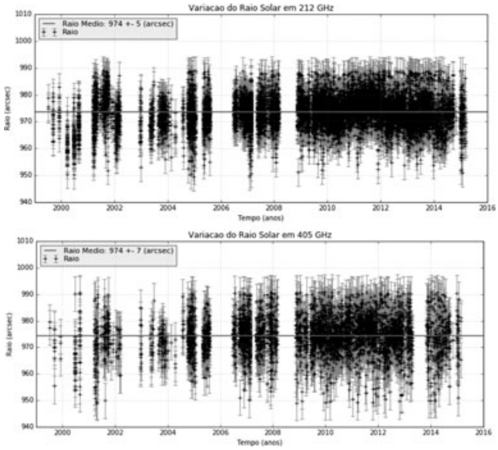

Figure 4. Fitted radius of the solar disk throughout the solar cycle at 212 GHz (above) and 405 GHz (below).

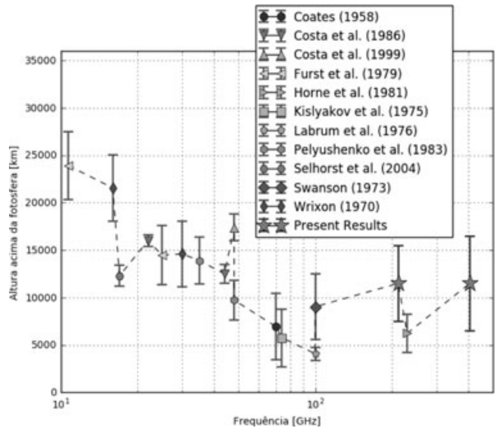

Figure 5. Height of emission above the photosphere as function of the frequency with previous results from other authors.

4. Conclusion

From the radii obtained – from the fit to the SST maps (Figure 4) – we could calculate their respective heights above the photosphere (Table. 1): the 212-GHz emission is produced at an altitude of 11,492±4000 km, whereas 405-GHz one is emitted at an altitude of 11,492±5000 km. In Figure 5 we can also compare our present rusults with previous ones from Coates (1958), Costa *et al.* (1986), Costa *et al.* (1999), Fürst *et al.* (1979), Horne *et al.* (1981), Kisliakov *et al.* (1975), Labrum *et al.* (1978), Pelyushenko & Chernyshev (1983), Selhorst *et al.* (2004), Swanson, P. N. (1973), Wrixon (1970).

The Sun's atmosphere is divided to three structures. According to Cox *et al.* (Ed. 2015), they are photosphere (from 0 to 525 km), chromosphere (from 525 to 2100 km) and the corona (from 2100 km and above). So, we can conclude that both emission frequencies are dominant at the corona layer.

Aknowledgements

Special thanks to MackPesquisa and IAU for the support and aid for the this event (IAUS 328) and to CAPES for the scholarship aimed at the postgraduate program of Geospatial Sciences and Applications.

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