EPSC Abstracts
Vol. 5, EPSC2010-99, 2010
European Planetary Science Congress 2010

Radio astronomical aspect of the solar convection zone

O.V. Arkhypov (1,2), A.V. Antonov (1,2) and M.L. Khodachenko (3)
(1) Institute of Radio Astronomy, Nat. Acad. Sc. of Ukraine, Kharkiv, Ukraine, (2) Kharkiv V. N. Karazin National University, Kharkiv, Ukraine (alexeyarkhipov@rambler.ru / Fax: +38-057-706-1415), (3) Space Research Institute, Austrian Acad. Sc., Graz, Austria (maxim.khodachenko@oeaw.ac.at)

Abstract

The processes in deep layers of a solar convection zone could be pronounced in the large scale activity, i.e., radio emissions of the Sun. We test this hypothesis with the millimeter radio-images of the Sun (Metsähovi Radio Observatory 1994-1998, 37 and 87 GHz) and the optical data (Mount Wilson 1998-2004, Fe I, 525.02 nm). It is found that the millimeter radio astronomy has certain prospects for remote sensing of the solar convection zone.

1. Introduction

Active regions on the solar surface are generally thought to originate from a strong toroidal magnetic field generated by a deep seated solar dynamo mechanism operating at the base of the solar convection zone [4]. The magnetic fields traverse the entire convection zone before they reach the photosphere to form the observable solar active regions with enhanced radio emission. This transport of the magnetic field could be used as a probe of the solar convection zone. For example, the differential rotation of the Sun could deform the activity pattern in the photosphere. We are searching for this effect in supergiant activity complexes with radio and optical data.

2. Distortion of supergiant activity complexes

To visualize the supergiant activity complexes of different scales, we construct a plot indicating position of Fourier-harmonic maxima found for every line of the solar radio map with the longitudinal wavenumber m=1 at various latitudes. The typical result of such a procedure is a spiral-like curve in polar diagram (Fig. 1b). More clearly spirals are visualized in Fig. 2 obtained with the synoptic charts of the intensity of the Fe I spectral line (5250.2 Angstroms, 1995-2007, Mount Wilson Observatory). In fact these spiral patterns depict the traces of the supergiant activity complexes [1].

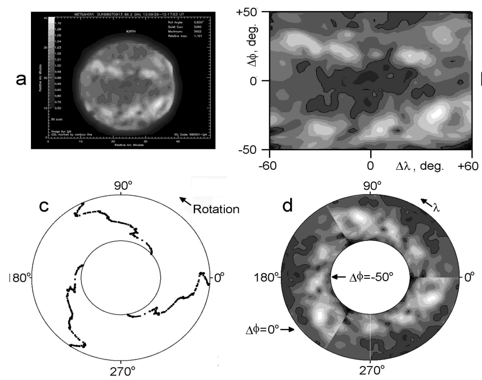

Figure 1: (a) Radio image of the Sun (July 9, 1998, 12:09-18 UT; 86.2 GHz; Metsähovi Observatory; http://kurp.hut.fi/en/sun/metsahovisun); (b) the cylindrical equal-area projection of the image; (c) the spiral type plot of Fourier-harmonic maxima found for every line of the map; (d) the polar projection of (b) for comparison.

To estimate the spiral curling, the parts of the spiral are compiled with a specific algorithm. For each spiral part we calculate the approximation with the method of least-squares. The histogram in Fig. 3 shows the obtained estimates for radio data. As activity complexes are fragmented, loop-like distortions appear in plots of Fourier-harmonic maxima, which mask the spirals and create two maxima of the histograms in Fig. 3. However, the spiral pattern appears statistically in form of dominating peaks in the histogram. These the most probable estimates of spiral curling are approximately equal in modulus but opposite in sign for northern and southern solar hemispheres. Their origin is due to the faster rotation of the solar equatorial belt.

It is natural to suppose that the initial geometry of

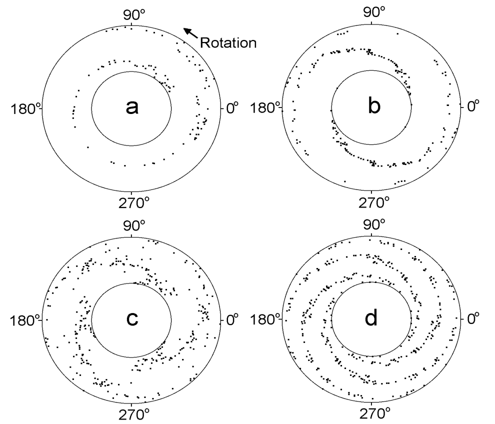

Figure 2: The spiral patterns (similar to Fig. 1c) for different m and the synoptic charts of the intensity of the Fe I spectral line (1995-2007, Mount Wilson; ftp://howard.astro.ucla.edu/pub/obs/synoptic_charts): a) m=1, north, rotation 1955.5; b) m=2, south, rotation 1981.5; c) m=3, south, rotation 1942.5; d) m=4, south, rotation 1985.5.

the magnetic structure (spot or inclined belt), emerging through the convection zone, is statistically symmetric relative its central meridian. In this case the corresponding plot of Fourier-harmonic extrema (similar to Fig. 2) would coincide with the meridian line. For a meridionally oriented magnetic feature near the tachocline one could estimate the time of the spiral curling (Fig. 4b) by the differential rotation. In particular, for m=1 the curling time is 150 40 days. This estimate agrees with the theoretical time of the emergence of magnetic flux from the bottom of the convection zone: 190 days [2]; 110-320 days [3].

3. Conclusions

1. The supergiant activity complexes show the spiral geometry in accordance with the differential rotation of the Sun during magnetic field transport through the solar convection zone. It was possible for the first time to estimate experimentally the time of magnetic-flux transport for the different longitudinal scales (m=1-5).

2. As such spiral patterns are found with mm-data too, the millimeter radio astronomy has certain prospects for remote sensing of the solar convection zone.

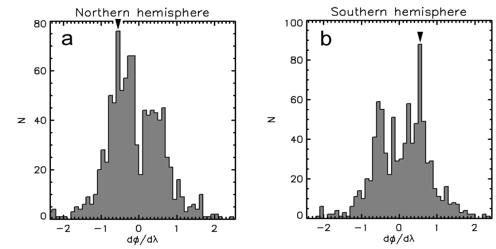

Figure 3: The arrowed peaks in the histograms of spiral curling estimates are an evidence of the spiral patterns in the used 188 solar radio images from the Metsähovi Observatory archive (37 GHz and 86-87 GHz; 1994-1998).

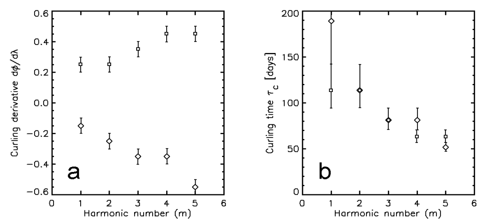

Figure 4: (a) The most probable values of the spiral curling is estimated for the Fe I charts from the histograms like in Fig. 3. (b) The corresponding estimates of the curling time are calculated for the differential rotation of the Sun. The Rhombs and the squares depict the data for the northern and southern hemispheres respectively.

References

[1] Bumba, V., Kleczek, J.: Basic Mechanisms of Solar Activity, Example Publishing House, D. Reidel Pub. Co., 1976, pp.47-67.

[2] Caligari P., Moreno-Insertis F., Schüssler M.: Emerging flux tubes in the solar convection zone. I, Astrophys. J., 441, pp. 886-902, 1995.

[3] Caligari P., Schüssler M., Moreno-Insertis F.: Emerging flux tubes in the solar convection zone. II, Astrophys. J., 502, pp. 481-492, 1998.

[4] Tobias S. M.: The solar dynamo, Phil. Trans. R. Soc. Lond. A., 360, pp. 2741-2756, 2002.