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The Void Probability Function in MDI magnetograms

S. Giordano, F. Berrilli, and D. Del Moro

Department of Physics, University of Rome “Tor Vergata”, I-00133, Rome, Italy
e-mail: berrilli@roma2.infn.it

Abstract. We investigate the spatial distribution of reticular clusters of magnetic features on the solar surface. For this purpose, we develop a void searching algorithm, such as those used in cosmology to study galaxy spatial distributions. We apply this method to a temporal series of large FoV MDI (Michelson Doppler Imager) magnetograms, to identify voids between magnetic structures and to extract their normalized Void Probability Function, which characterizes the scale distribution of magnetic inter-cluster voids. The histogram of the void dimensions shows a pronounced peak for small dimensions (1.76 Mm) and a large spread in the individual cell sizes, up to ≃ 60 Mm.

Key words. Sun: magnetic fields - Methods: statistical

1. Introduction

The dataset used in this work consists of 160 high resolution magnetograms acquired with the Michelson Doppler Imager (MDI) in different days from April, 1996 to December, 1997. We selected only magnetograms with a low activity so that only quiet network was present on the solar surface. All images were rebinned 512×512, leading to a pixel scale of 1.21 arcsec/pixel. The surface distribution of solar magnetic features is identified by setting a threshold equal to $3\sigma_{mag}$, which corresponds on average to 15 G. In this way we obtain a two-level representation of the magnetic field: when the absolute value of a pixel of the magnetogram will be greater or equal to the threshold value, the corresponding pixel of the two-level representing map will be set equal to 1; otherwise, it will be set equal to 0. To reduce false detections, even at the risk of missing active pixels, we reject all isolated pixels above the given thresholds assuming that they are noise.

2. Void searching algorithm

Void searching algorithms are largely used in cosmology to study the spatial galaxy distribution of the Universe. The most prominent features of the large scale structure of the Universe are voids, the discovery of which is important for theoretical models about the origin of the structure of the Universe.

For each application, the main goal of a void searching algorithm is to detect voids and quantify their properties in an automated and objective manner, not biased by the human eye.

In this work we adopted the algorithm developed by Aikio & Mähönen (1998) in order

Send offprint requests to: F. Berrilli

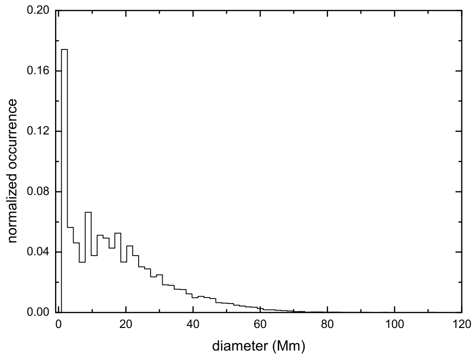

Fig. 1. Distribution of void diameters (in Mm) for the 160 MDI binarized magnetograms. The histogram is normalized to area unity.

to find voids in three dimensional redshift surveys.

Before implementing the algorithm, we have to define a void. Let us consider a distribution of particles in a square region $L^2 \in \Re^2$ with side length *L*. We define a scalar field, called *distance field* (DF), $D : L^2 \longrightarrow R$ as the distance of a given point *x* in L^2 to the nearest particle: The local maxima of DFs, which are the points in L^2 with the longest distance to the nearest particle correspond to the "centers" of empty regions. To numerically calculate the DF, we divide the region L^2 into k^2 *elementary cells*, where $k = L/s$ and *s*, called a *resolution parameter*, gives the spatial resolution of the void analysis. For each elementary cell, we calculate the minimum of distances to the particles, so obtaining a discrete DF, D(x). Then we calculate the local maxima of DF, (let M_i be the cell corresponding to the maximum of DF). It is possible that more than one maximum of a DF, with approximately the same values of the DF, falls inside a void. Such local maxima belong to subvoids of the same void.

The result that this algorithm directly gives is the main radius of the voids, R_V, defined as the maximum of the DF inside the void. By applying the void searching algorithm we can study the distribution of void radii.

3. Applying the void searching algorithm to MDI magnetograms

We present here some results obtained by applying the void searching algorithm to a series of MDI magnetograms.

In Fig. 1 we report the distribution of void diameters. It is obtained by summing the histograms of the dimensions of the voids identified in the 160 analyzed two level-maps. The histogram is normalized to area unity. As a first result we note that the histogram is characterized by a pronounced peak for small dimensions (1.76 Mm). Two effects contribute to produce this small scale peak. First, it is possible that the algorithm is identifying voids on a smaller (granular) scale, revealing that some magnetic structures organize themselves on such a scale. The second explanation derives from the fact that the solar network is not a continuous structure, but it is made up of single and not connected magnetic structures. While our eye is capable of "joining the dots" and identifying a number of structures as lying on the same "contour" that identifies a void, the algorithm cannot. As it is based on a computation of distances, it might identify a void between two close but not connected structures, belonging to the network. This could lead to an apparently high count of small voids. Apart from the first peak, the histogram shows a large spread in the individual cell sizes, up to $\simeq$ 60 Mm.

References

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