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A comparison of void distribution function of two solar minima

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Abstract: The latest solar minimum, between cycles 23 and 24 had been exceptionally quiet and long lasting. To investigate the difference between the last two minima, we focused on the magnetic patterns on solar surface as recorded by SOHO/MDI high-resolution magnetograms.
We used daily samples of 191 images (August 1996 - February 1997) and 511 images (January 2008 – June 2009) respectively, and considered the void, i.e., magnetic underdense region, distribution function as the indicator of solar activity.
To single out voids and to quantify their intrinsic pattern, we applied a fast circle-packing-based algorithm to the high-resolution magnetograms during the solar activity minima.

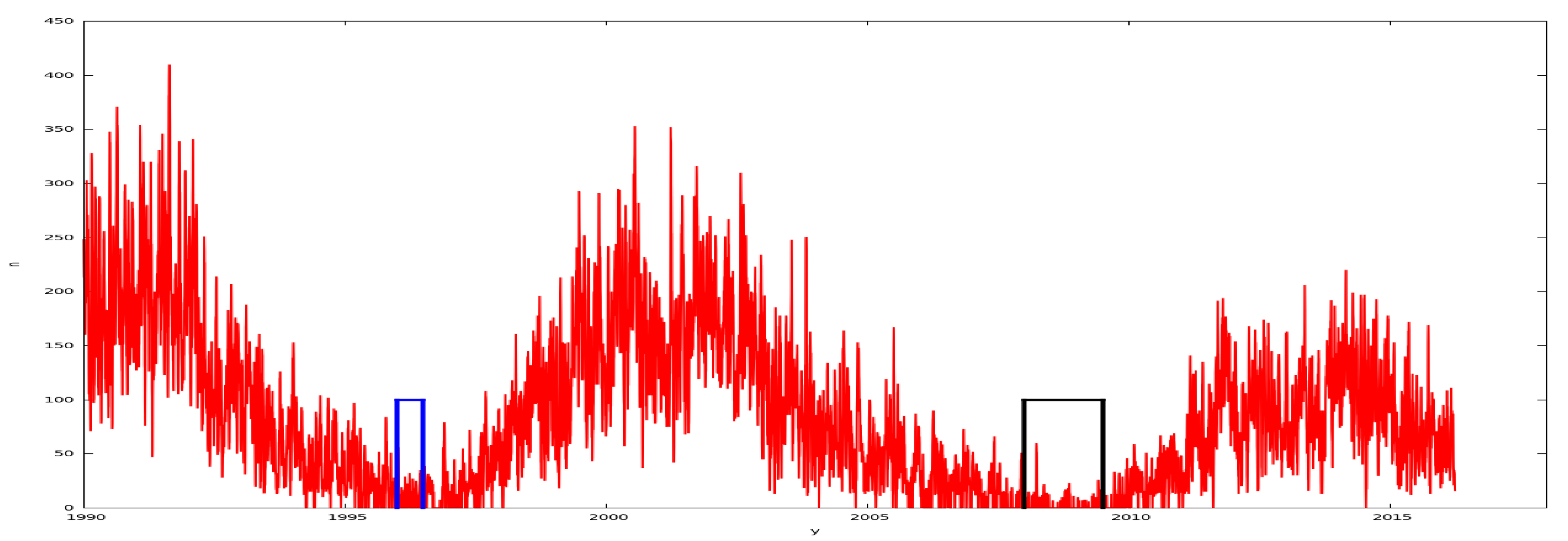


Figure 1
- red: sunspots number 1990-2016
- blue box: dataset 1996-7 (191 magnetograms)
- black box: dataset 2008-9 (511 magnetograms)

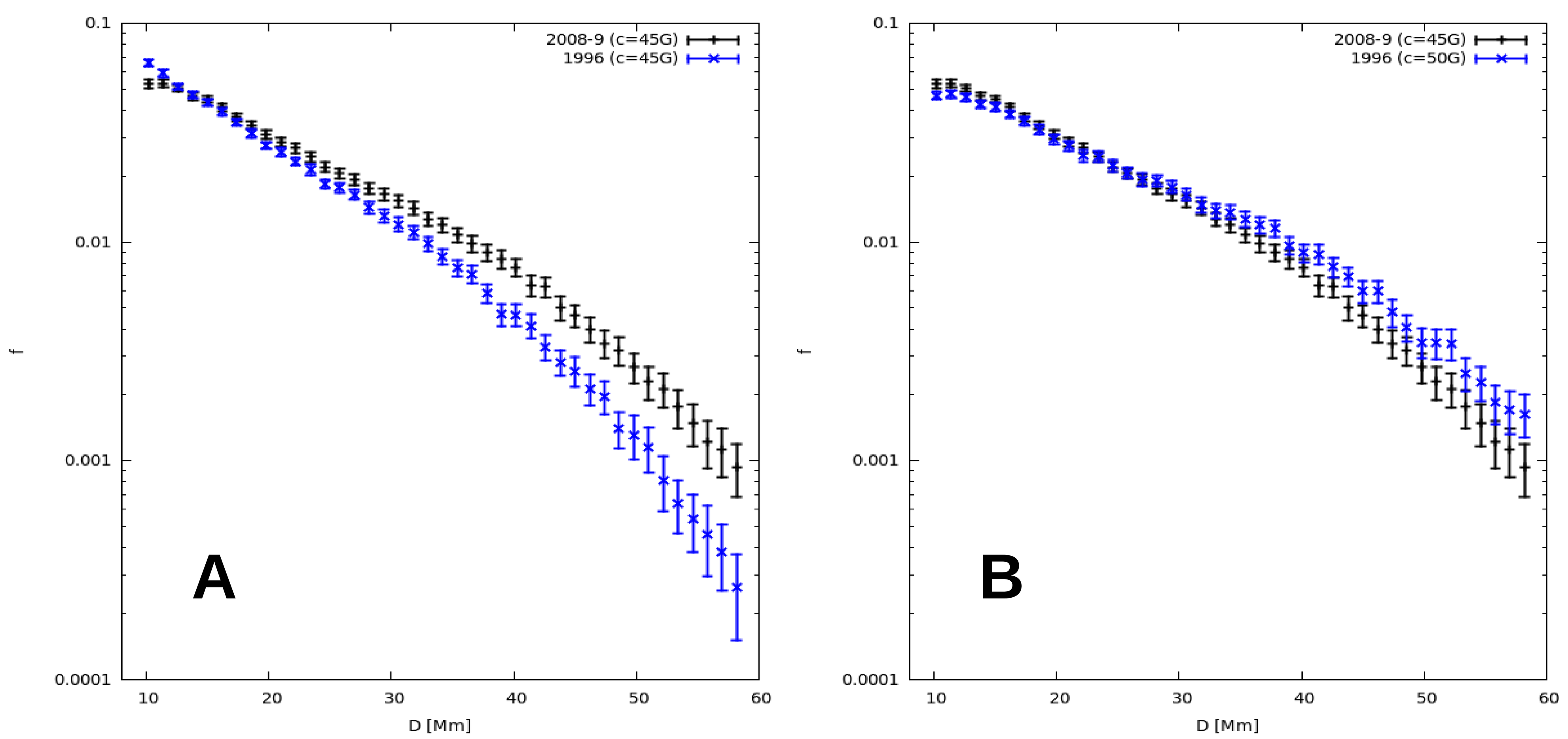


Figure 2
On the left (A), the VDFs resulting by applying the same cutting threshold (c = 45 G) to both the datasets. On the right (B), we slightly increased the 1996 thresholds (c=50 G). While keeping the general shape of the distribution, the change in 1996 slope shows that the *exact value* of the threshold is quite critical.

The turbulent convective flows on the solar surface govern the motion of magnetic elements. Such elements are arranged in typical patterns which are observed as a variety of multiscale magnetic underdense regions (voids).
The object of this work is to compare the *size* distributions of these voids in the two latest minima of the solar cycle.
We consider as the parameter of our statistics the *equivalent diameter* of voids D_e, defined as:

$$D_e = 2\sqrt{\frac{area}{\pi}}$$

Dataset

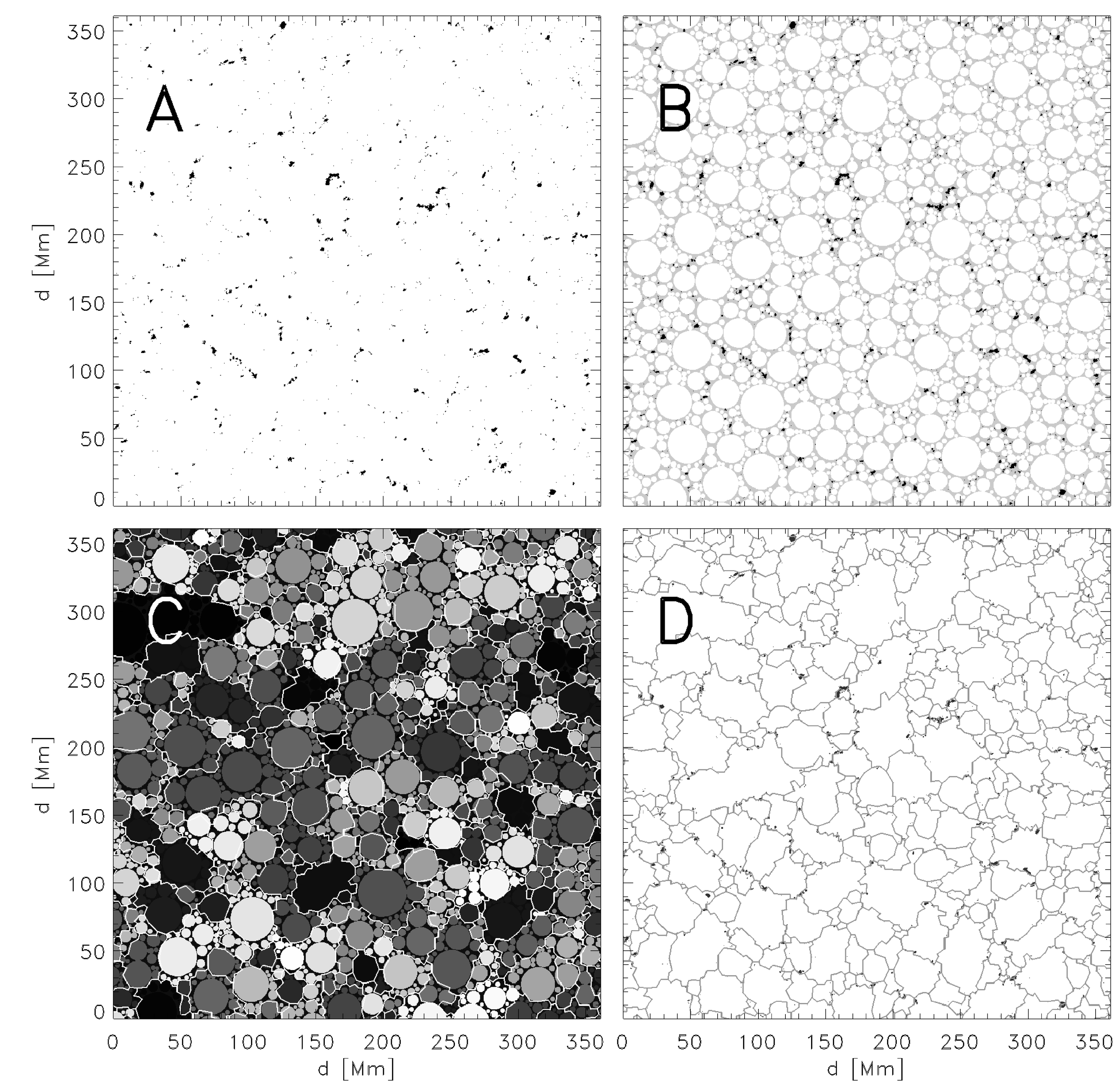
We used high resolution SOHO/MDI magnetograms (Lev1.8): the images have a field of view of 11'×11' with a plate scale of 0.625" per pixel and a (diffraction-limited) resolution of 1.25".
We analyzed two datasets of magnetograms with daily rate (Figure 1):

- from Aug 1st, 1996 to Feb 28th, 1997 (7 months)
- from Jan 1st, 2008 to Jun 30th, 2009 (18 months)

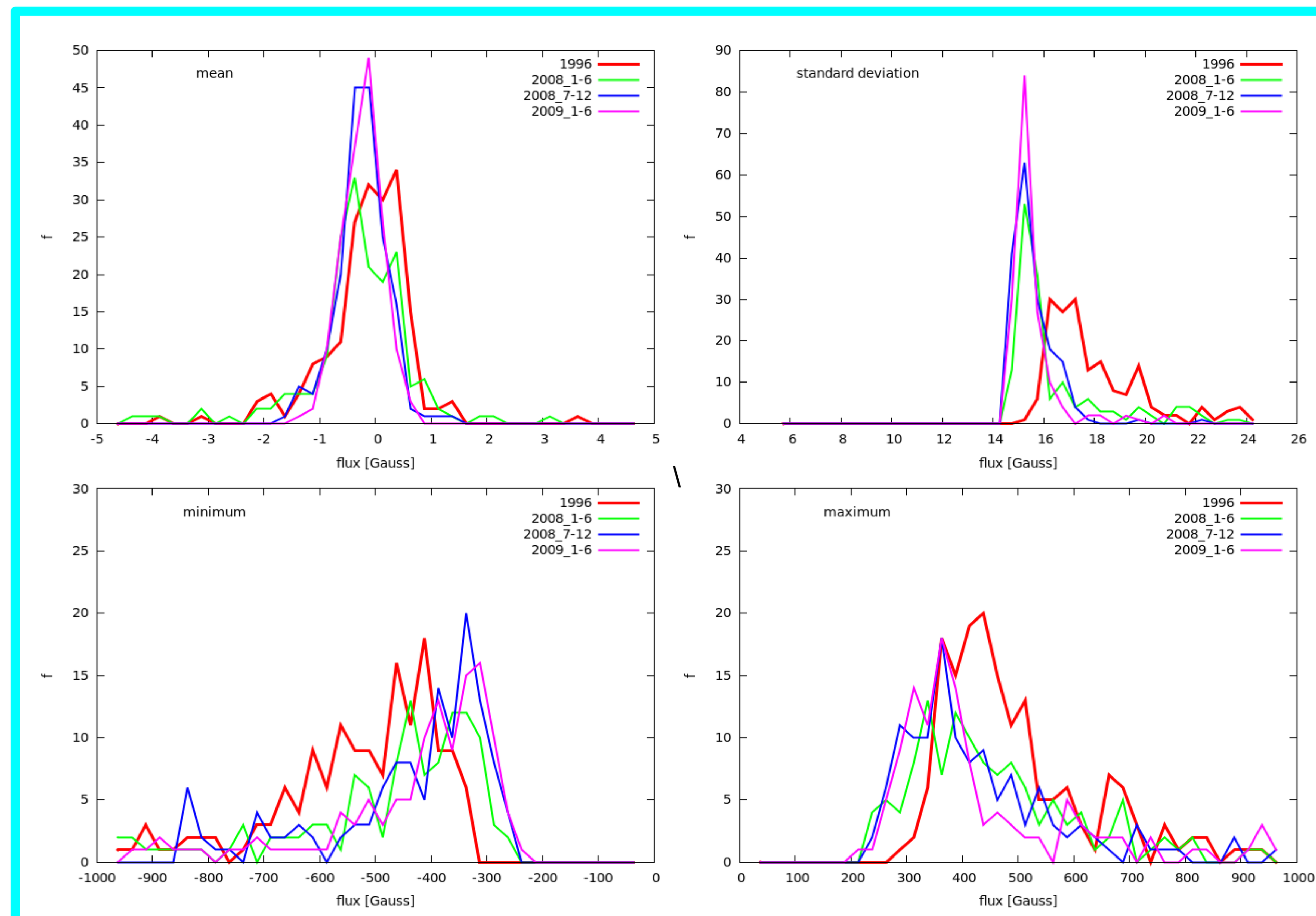
Method

After excluding from our datasets the images which show strong magnetic activity, the total number of considered magnetograms was 702.
To outline the magnetic structures in each image we used a fixed threshold segmentation with |B| > 45 G (~3σ in the 2008-9 dataset).
The void detection algorithm (see the blue box on the right) singled out ~250000 voids from the 2008-9 dataset and >100000 from the 1996-7 dataset, giving us a huge statistics throughout the datasets.
The resulting VDF is shown in Figure 2 (left). From both the datasets, we have established that the VDF shows an almost identical quasi-exponential decay in the observed range, but emerged also a little difference in the slopes of distributions.
The graph on the right in the same figure shows what happens if we rise of 5 G the threshold of the 1996 dataset (it means that we considered a little increase of 1996's σ of about 1.6 G). The resulting change in distribution slope exceedingly compensate the difference with the distribution of 2008-9 dataset.

The *fast* void detection algorithm



A: the magnetic structures (in black) are defined on magnetograms by a 3σ threshold
B: a *circle packing* is obtained by recursively defining a distance field (DF) maximum
C: the circles are clustered by the "climbing algorithm" from their centers on the DF
D: the resulting voids with the magnetic structures on their edges



SOHO/MDI: data products stability

To perform a rapid analysis of the 'stability' of MDI's products, we calculated the trivial statistics of pixel intensity. We divided the series of magnetograms in four 6-month sets (one for 1996 minimum and three for 2008-9 minimum).
In particular:
- top-left: distributions of pixels average
- top-right: distributions of pixels standard deviation
- bottom: distributions of minimum (left) and maximum (right) pixel

We can observe a substantial stability in averages, maxima and minima, but the slight difference in the standard deviation seems significant between the 1996 dataset and the 2008-9 one.
Unfortunately the question whether this difference is due to instrumental change or to a different solar activity is still open.

Conclusions

- **The monotonic distribution and the lack of marked features in the 10-60 Mm range (absence of a preferred scale) does persist in both the minima**
- **The VDFs seem to be almost identical with just a little correction of the cutting threshold (<5 G)**
- **The origin of this correction can be ascribed to a real change of solar activity, but also to a decay of MDI detectors (see the cyan box on the left)**

Further reading

- Berrilli, Scardigli, Giordano, Solar Physics 282 (2), 379-387
- Berrilli, Scardigli, Del Moro, A&A 568, A102