Examination of the EUV intensity in the open magnetic field regions associated with coronal holes

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Abstract

Coronal holes can be identified as the regions with magnetic field lines extending far away from the Sun, or the darkest regions in EUV/X-ray images with predominantly unipolar magnetic fields. The aim of this study is to investigate the conditions leading to different brightness of the OMF regions, and to provide a means to predict whether an OMF region would be bright or dark. The examination of the relationship between I_{193} and f_s reveals a weak positive trend between $\log I_{193}$ and $\log f_s$ with a correlation coefficient ≈ 0.39. As a first order approximation, the positive relationship is determined to be $\log I_{193} = 0.62\log f_s + 1.51$ based on the principle of the Whitening/Dewhitening transformation.

1. Introduction

Coronal holes are **theoretically** the regions with magnetic field lines extending far away from the Sun, or **observationally** the darkest region observed from EUV or X-ray images, with predominantly unipolar magnetic fields.

The EUV intensity, however, is a result of **complicated physical processes**. The two definitions of coronal hole need not be perfectly overlapped.

The expansion factor (f_s) is one of the important parameter to describe the open magnetic structure, and may potentially affect the **density** or the **heating** in the solar corona, which would moreover affect the EUV brightness.

The sketch below shows three cases with sub-radial expansion (f_s<1), radial expansion (f_s=1) and super-radial expansion (f_s>1).

In this study, we would like to examine the relationship between the expansion factor and the EUV intensity.

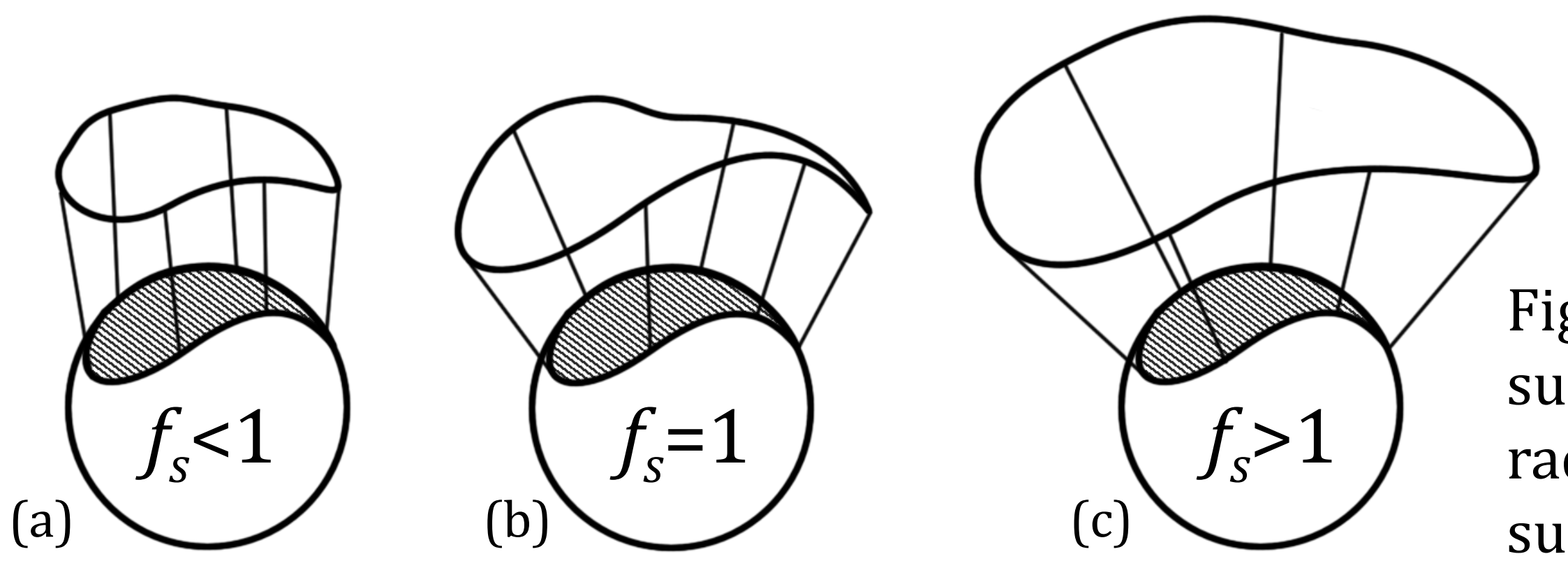


Fig 1. Coronal holes with (a) sub-radial expansion (f_s<1) (b) radial expansion (f_s=1) and (c) super-radial expansion (f_s>1).

2. EUV coronal holes (LIR$_{193}$)

The EUV maps are constructed using the 193Å imaging of Atmospheric Imaging Assembly onboard Solar Dynamics Observatory (SDO). Magnetic field maps are constructed using the imaging of Helioseismic and Magnetic Imager onboard SDO.

The coronal holes are determined based on the method proposed by Krista and Gallagher (2009)[2]. In the procedure, **thresholding** is applied to the EUV maps to extract the low intensity regions, and then the magnetic field maps are used to determine whether the region is **unipolar** or **bipolar**.

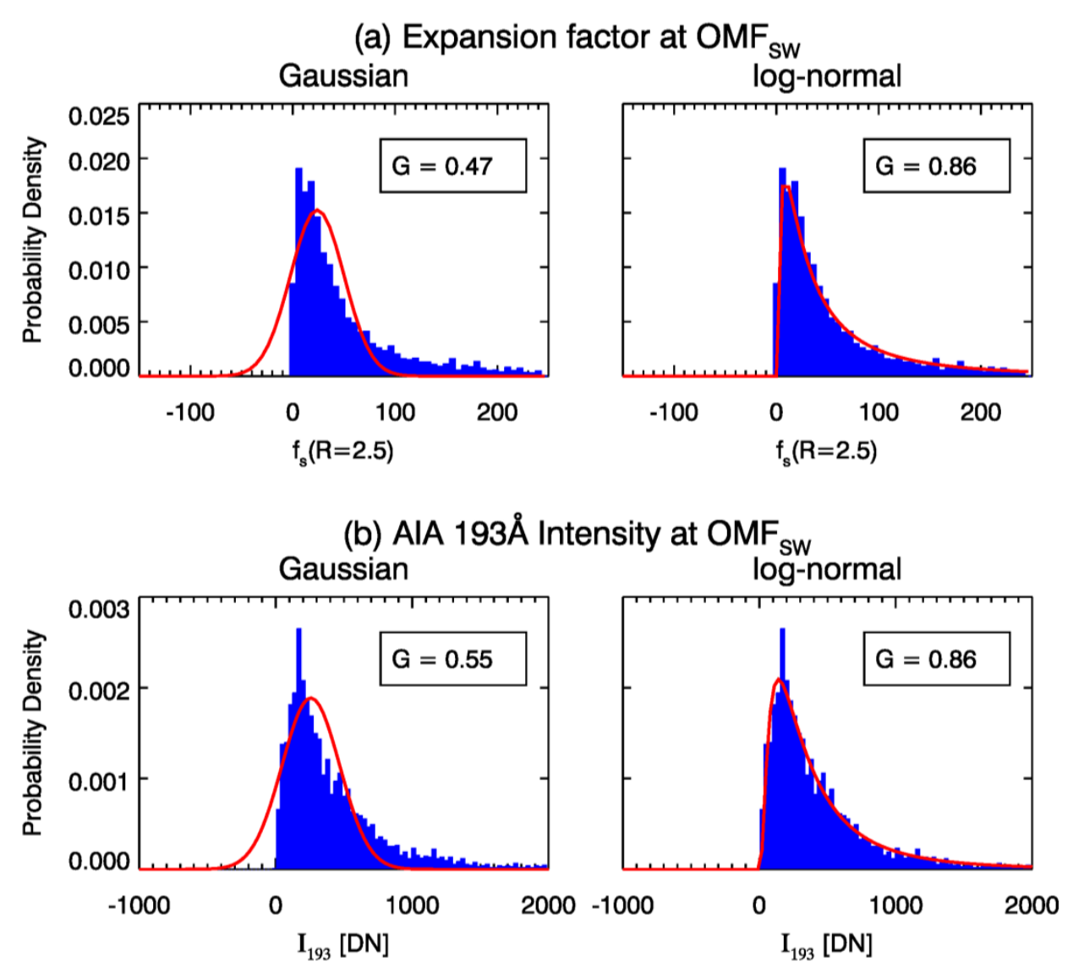
3. Open magnetic field coronal holes (OMF)

The magnetic field maps from Wilcox Solar Observatory are used.

The global magnetic field structure is then constrcuted using the Potential Field Source Surface model (Schatten, 1969)[3].

The open magnetic field lines are determined by **tracing field lines** from 2.5 solar radius to 1.0 solar radius. The OMF coronal holes are therefore their **footpoints** on 1.0 solar radius.

4. Distributions of I_{193} and f_s

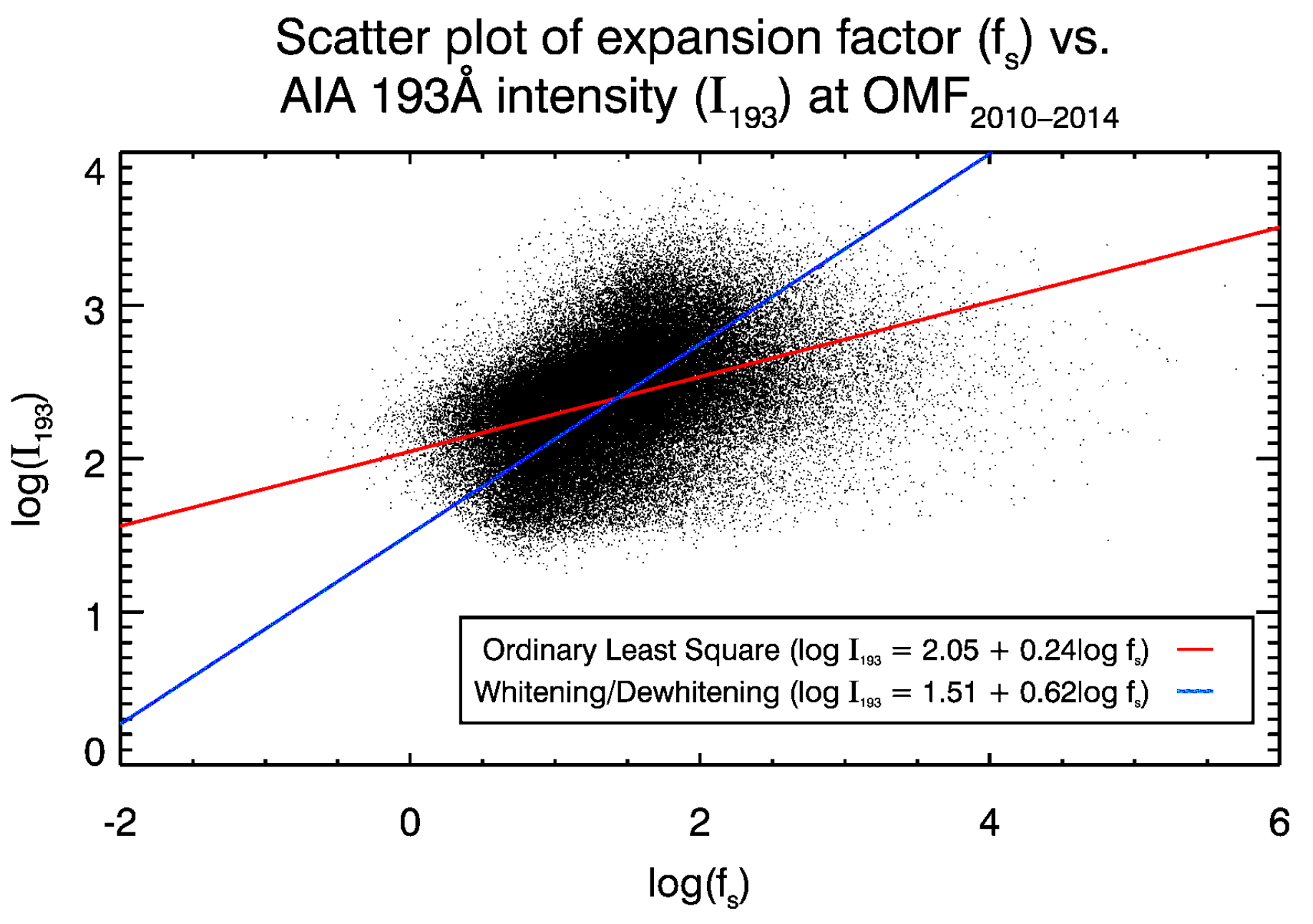


We compare the distributions between the expansion factor (f_s) and the AIA 193Å (I_{193}) intensity at the location of high-speed solar wind sources.

Figure 2. shows that both physical quantities distribute more like log-normal distribution (higher goodness-of-fit G), instead of normal distribution.

Fig 2. Distributions of (a) fs and (b) I193 at the location of high-speed solar wind source.

5. The relationship between I_{193} and f_s



We examine the scatter plot to search for possible relationship between the two.

Figure 3. reveals a **weak positive trend** between $\log f_s$ and $\log I_{193}$, with correlation coeffcient ≈ 0.39.

We then apply two methods to obtain the linear relationship.

Fig 3. Scatter plot of f_s and I_{193}. Red line shows the regression line obtained by Ordinary Least Square. Blue line shows the Whitening/Dewhitening transformation.

Method 1. Ordinary Least Square

The Ordinary Least Square (OLS) minimizes the squares of vertical errors between the data and the regression line.

The linear relationship is $\log I_{193} = 0.24\log f_s + 2.04$.

Method 2. Whitening/Dewhitening

The Whitening/Dewhitening (WD) (Mayer et al. 2003)[4] transforms one normal distribution into another normal distribution with different mean and standard deviation. This technique is often used in the cross-calibration between satellites.

The linear relationship is $\log I_{193} = 0.62\log f_s + 1.51$.

6. Evaluation of the relationship

Using the linear relation above, and the same intensity threhold obtained before, we can predict EUV coronal holes from OMF coronal holes.

The result shows that OMF coronal holes generally coincide with EUV coronal holes, except that some regions are bright. After the application of two regressions, the result obtained from OLS shows few dark pixels (small f_s). On the other hand, WD retains most dark pixels while removing bright ones (large f_s).

Conclusion

The result reveals a weak positive trend between $\log I_{193}$ and $\log f_s$, with correlation coefficient ≈ 0.39.

Using OLS and WD method, we obtain their linear relationship.

The comparison shows that **OLS is too flat** to produce dark pixels, and WD can remove many OMF pixels that do not coincide with LIR$_{193}$ pixels, while retaining many OMF pixels that coincide with LIR$_{193}$ pixels.

Therefore the linear relationship **$\log I_{193} = 0.62\log f_s + 1.50$ obtained by WD is a better predicter** than the one obtained by OLS.

References

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