Geometrical properties of coronal holes and filament channels extracted from SDO/AIA 193Å images

M. Reiss [1], M. Temmer [1], T. Rotter [1], S.J. Hofmeister [1], A.M. Veronig [1]

[1]University of Graz, Institute of Physics, IGAM-Kanzelhöhe Observatory, NAWI Graz, Graz, Austria

Introduction

Coronal holes (CH) play an important role in geomagnetic storm activity [1]. They coincide with rapidly expanding open magnetic fields and are the source regions of the high speed solar wind streams (HSS). In a previous study, we developed an automated method for the identification and extraction of CH regions [2]. Currently the algorithm is used on SDO/AIA 193Å data for the automatic extraction of CH areas and forecasting of solar wind speed at 1 AU. The testing phase demonstrated that filament channels (FCs) are sometimes erroneously identified as CHs. To improve the solar wind forecasting method we need to distinguish FCs from CHs in EUV images. Due to the fact that the axial flux of the flux rope varies along the FC, a characteristic elongated structure is likely to appear [3]. In this study, we assess the benefit of geometrical classification methods for improving the distinction between CHs and FCs [4]. Based on SDO/AIA 193Å images recorded during the period 2011 to 2013, we present new geometrical classification methods in comparison with well known shape measures from literature. The results indicate that the presented geometrical classification techniques have the potential to reduce CH classification errors and will subsequently be applied as an screening technique in our solar wind forecast algorithm.

Motivation

We developed a detection method to obtain fractional CH areas from SDO/AIA 193Å images (cf. Fig. 1). CH areas extracted at a 15° slice at the solar meridian reveal a high correlation ($CC \sim 0.8$) with the solar wind measured ~4 days later in-situ at 1 AU [2]. Based on this, we provide automated forecasts of HSS arriving at Earth four days in advance.

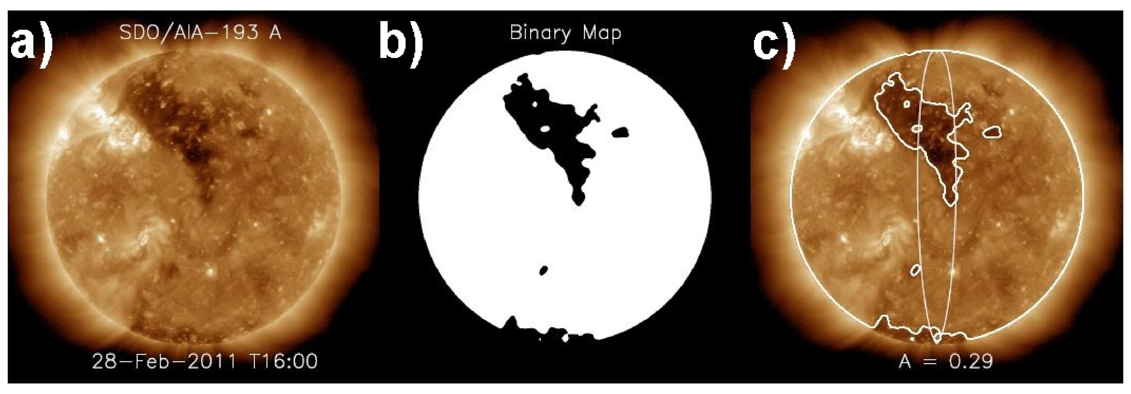
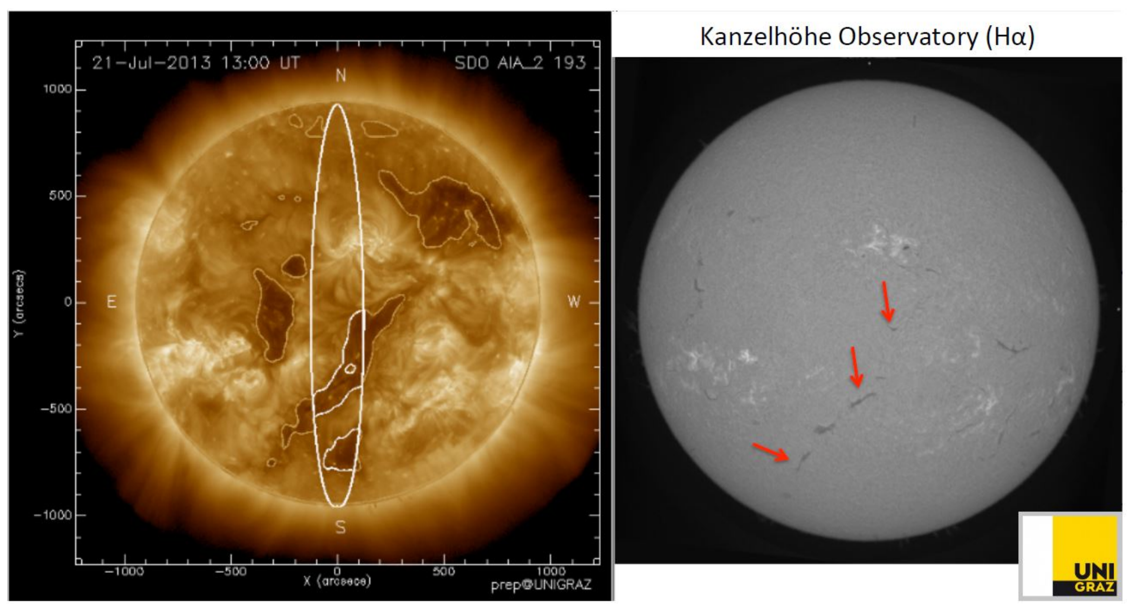


Figure 1: (a) Calibrated SDO/AIA 193Å image on 28-02-2011. (b) Resulting binary map, after application of erosion and dilation. (c) CH binary map overlaid on the original EIT image. For Earth-affecting HSS only areas of CHs within a slice of ±7.5° around the central meridian are taken into account.

Problem Statement

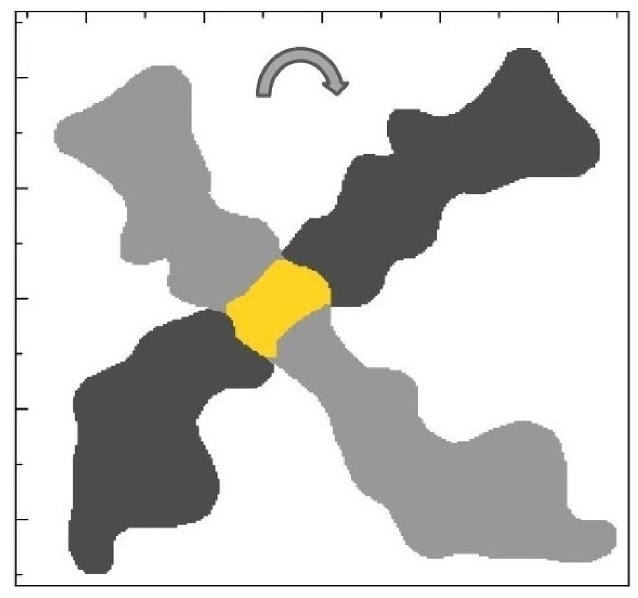
FCs detected as CHs decrease the quality of our forecast algorithm (cf. Fig. below)!



Investigated Solution:
Considering the geometrical properties of FCs we aim to improve the CH detection algorithm. The literature provides shape measures like compactness (ratio between perimeter squared and area) and elongation (ratio of longest and shortest extension). In order to investigate the geometrical properties of CHs and FCs in detail, we propose two alternative shape measurements.

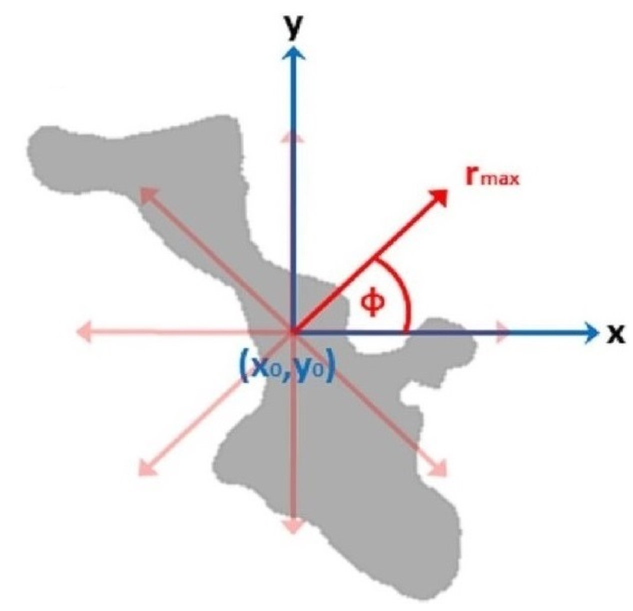
Proposed Methods

i) Symmetry Analysis



After the application of discrete geometrical transformations like rotation, reflection and a composition of both, we sum over the overlapping object pixels and calculate the total overlap in percentage. We propose to use the average overlap in percentage of all transformations which provides different structures than the original one as a shape descriptor.

ii) Direction dependent analysis



We centre each pixel (x_0, y_0) of a structure and count the number of pixels within a given direction ϕ and distance r_{max}. Computing the average number of object pixels for each direction leads to the function $f(\phi)$. The standard deviation of $f^*(\phi) = f(\phi)/f_{max}(\phi)$ is found to be a reliable shape measure for this purpose.

First Results - Univariate Analysis

Fig. 2 shows the resulting shape measures for CHs and FCs by applying different geometrical methods. The larger the differences between the boxes, the better the distinction between CH and FC. We obtain for the conventional shape measures from literature small differences (Fig. 3 a-b), but larger differences with our newly developed methods (Fig. 3 c-d). The results reveal that FCs can be modelled as largely asymmetric structures aligned along a preferred direction, which is exactly the geometry covered by our methods.

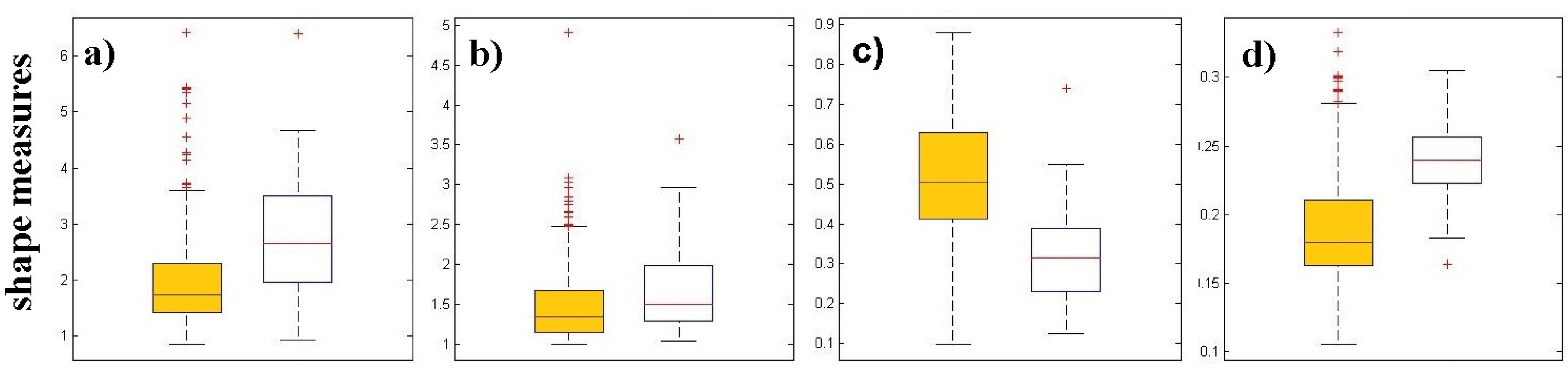


Figure 2: Comparison between standard shape measures and proposed geometrical classification methods for coronal holes (orange boxes) and filament channels (white boxes). On each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers show the $\pm 2.7\sigma$ range covering 99.3 % of data. Outliers, marked as red crosses, were plotted individually. The boxplots are ordered from worst to best according to their relevance for a distinction between CHs and FCs. (a) Elongation, (b) Compactness, (c) Symmetry analysis, (d) Direction dependent analysis.

We interpret the elongated structure of FCs in contrast to CHs in terms of the sheared arcade or weakly twisted flux rope model, having a magnetic field which is dominated by the axial component. In the dip of the helical windings the dense/cold prominence material is located leading to the observed elongated dark structures observed at EUV wavelengths. (see e.g., [3]).

Conclusion & Outlook

The results of this research support the idea that the proposed geometrical methods have the potential to decrease CH classification errors. This research will serve as a basis for future studies were we want to investigate the benefit from textural features for the analysis of the intrinsic texture information of CHs and FCs in EUV and magnetogram images.

References

[1] Tsurutani et al. *Geophys. Res.* **111**, 7., 2006
[2] Rotter et al. *Solar Phys.* **281**, 793-813, 2012
[3] Mackay et al. *Space Science Rev.* **151**, 333-399, 2010
[4] Reiss et al. *CEAB*, accepted, 2014