On loops and veils

V. Uritsky

The Coronal Veil

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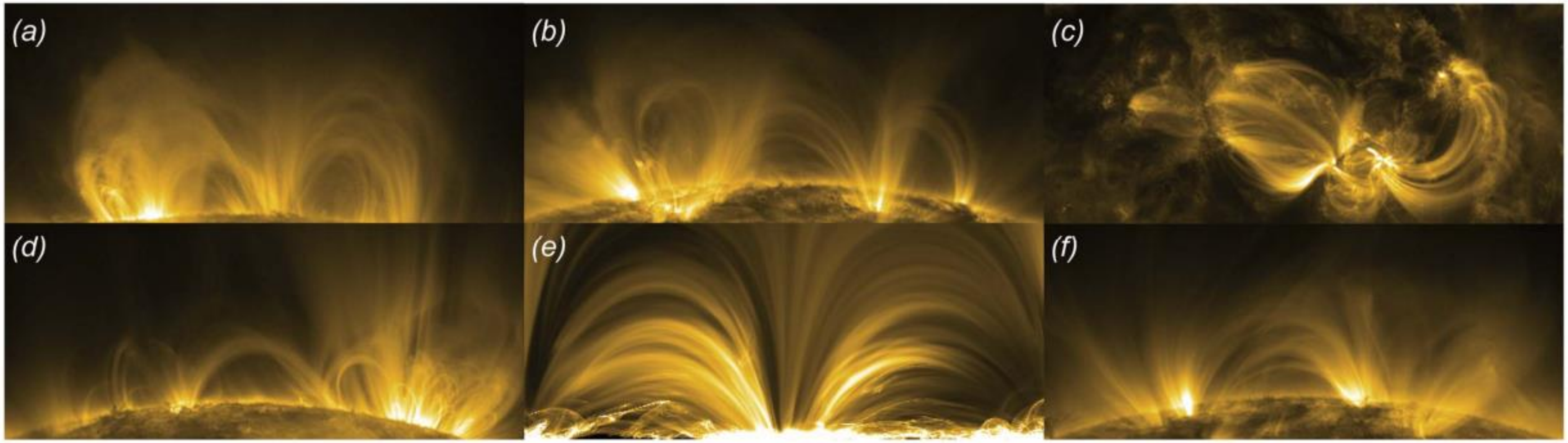
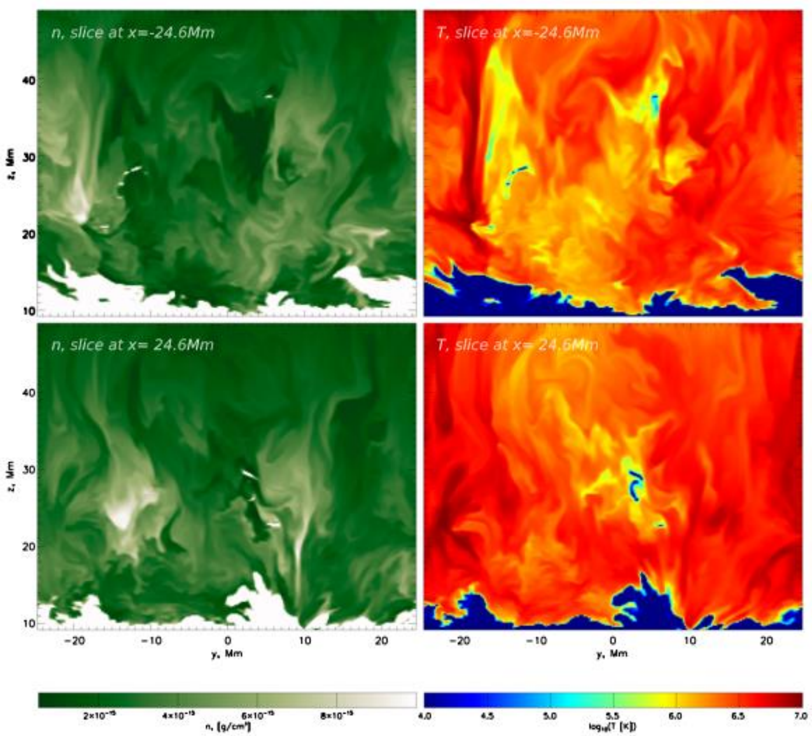
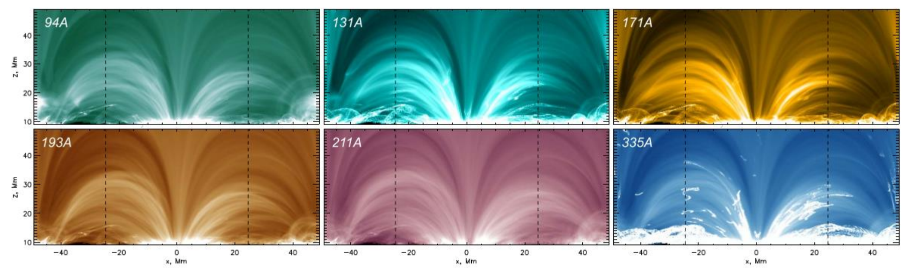
Abstract

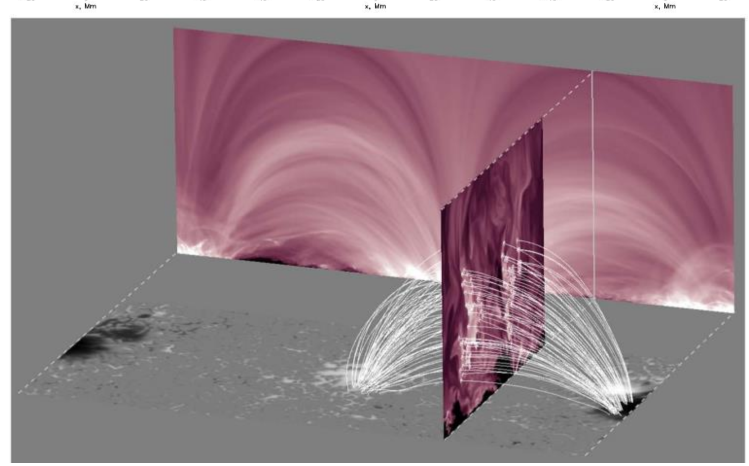
Coronal loops, seen in solar coronal images, are believed to represent emission from magnetic flux tubes with compact cross sections. We examine the 3D structure of plasma above an active region in a radiative magnetohydrodynamic simulation to locate volume counterparts for coronal loops. In many cases, a loop cannot be linked to an individual thin strand in the volume. While many thin loops are present in the synthetic images, the bright structures in the volume are fewer and of complex shape. We demonstrate that this complexity can form impressions of thin bright loops, even in the absence of thin bright plasma strands. We demonstrate the difficulty of discerning from observations whether a particular loop corresponds to a strand in the volume, or a projection artifact. We demonstrate how apparently isolated loops could deceive observers, even when observations from multiple viewing angles are available. While we base our analysis on a simulation, the main findings are independent from a particular simulation setup and illustrate the intrinsic complexity involved in interpreting observations resulting from line-of-sight integration in an optically thin plasma. We propose alternative interpretation for strands seen in Extreme Ultraviolet images of the corona. The "coronal veil" hypothesis is mathematically more generic, and naturally explains properties of loops that are difficult to address otherwise—such as their constant cross section and anomalously high density scale height. We challenge the paradigm of coronal loops as thin magnetic flux tubes, offering new understanding of solar corona, and by extension, of other magnetically confined bright hot plasmas.

Malanushenko et al., ApJ 2022



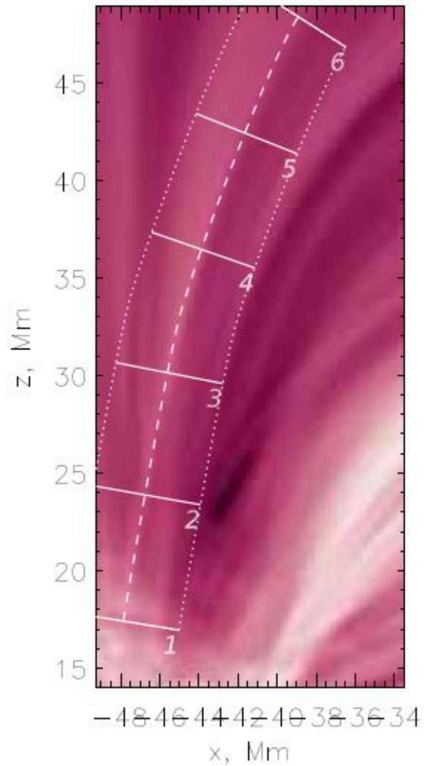


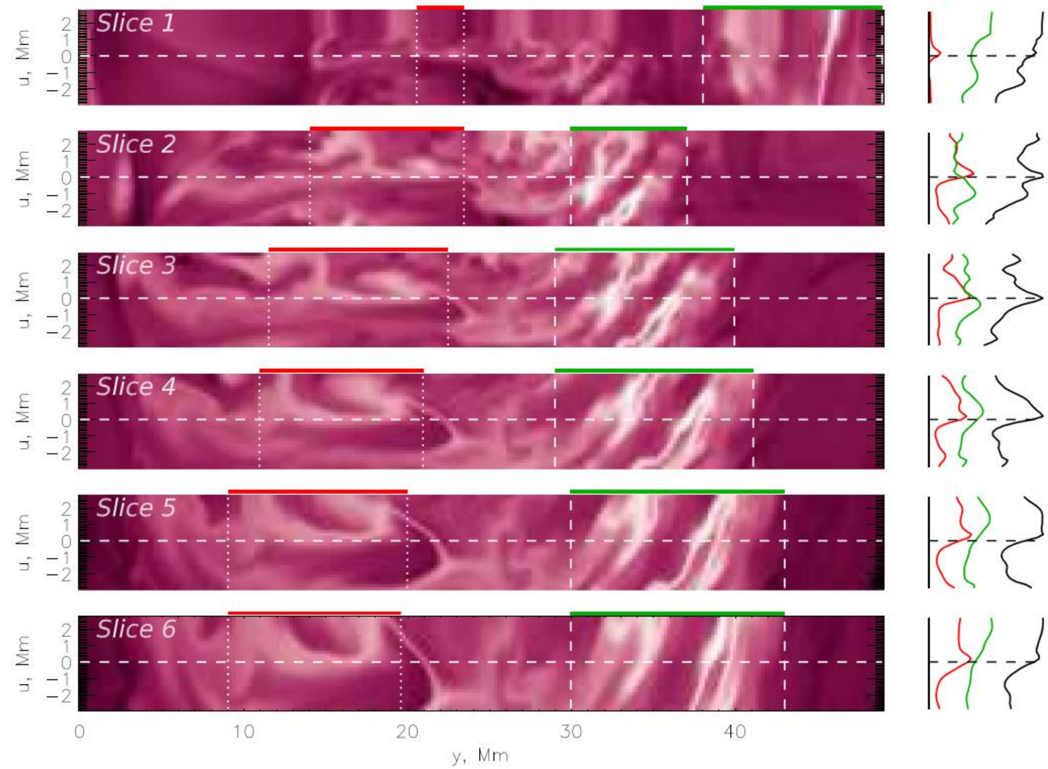




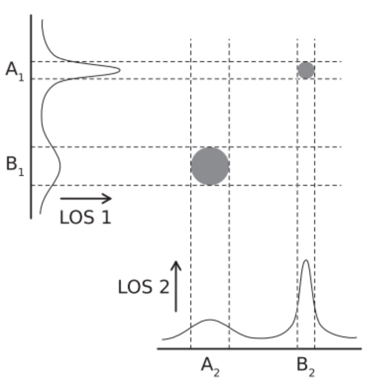
MURaM MHD code (Vogler et al, 2005)

Malanushenko et al., ApJ 2022

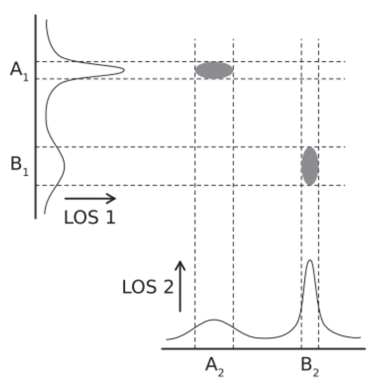


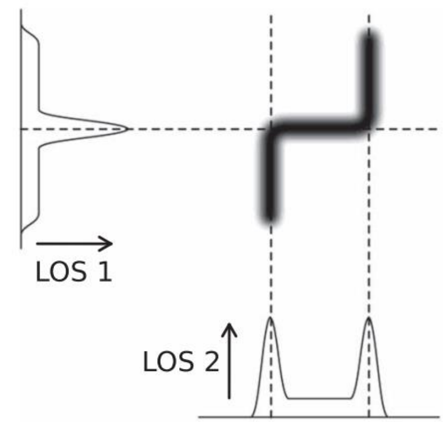


Solution 1



Solution 2





Plato’s cave allegory (424-348 BC)

Plato’s cave allegory

Plato theorizes that the group of people tied up in the cave would assume that the shadows they see on the wall are reality. This false reality is all that the people in the cave know. They have no true knowledge of the real world. However, they fully believe that what they see on the cave wall is reality, **and even try to name the shadows they see passing by**.

Plato’s cave allegory further proposes that one of the prisoners escapes or gains freedom from the cave. After understanding greater reality, the prisoner returns to the cave to try to compel the other prisoners to experience this new world, but when he returns to the cave, his eyes can no longer see in the darkness.

Now, **the prisoners mock the freed prisoner because he cannot see the shadows of objects on the wall in front of him**. Plato theorizes that **they may even become violent** to the other prisoner as he continues to describe the outside world (watch out !!! :)

Consistency checks for the shadows on the coronal cave walls

1. Comparing data with synthetic shadows from turbulent MHD models
   WITHOUT well-defined loops / loop strands

2. Comparing data with synthetic shadows from MHD models
   WITH well-defined loops / loop strands

Structures in magnetohydrodynamic turbulence: Detection and scaling

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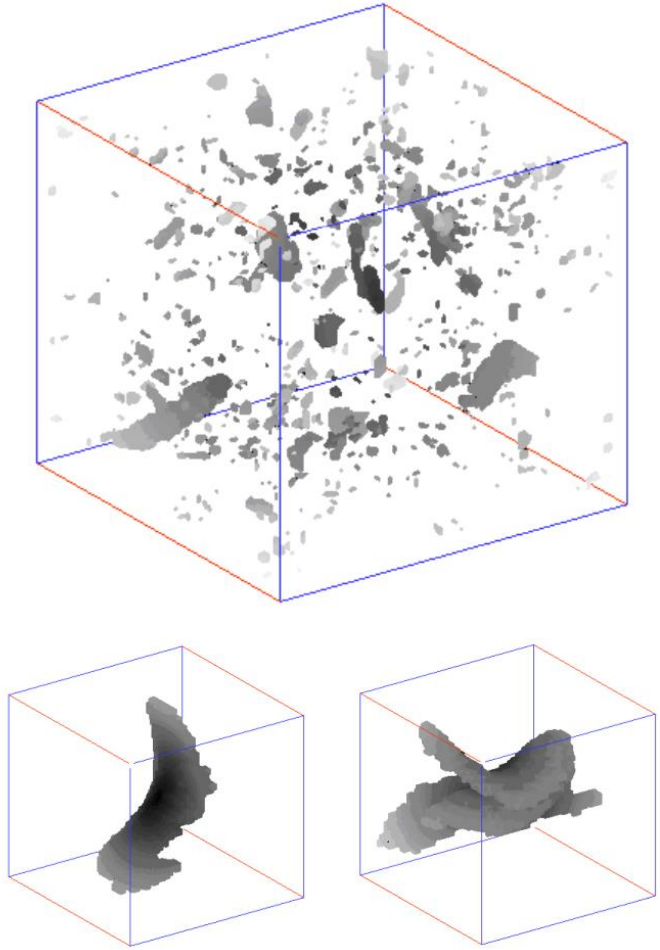
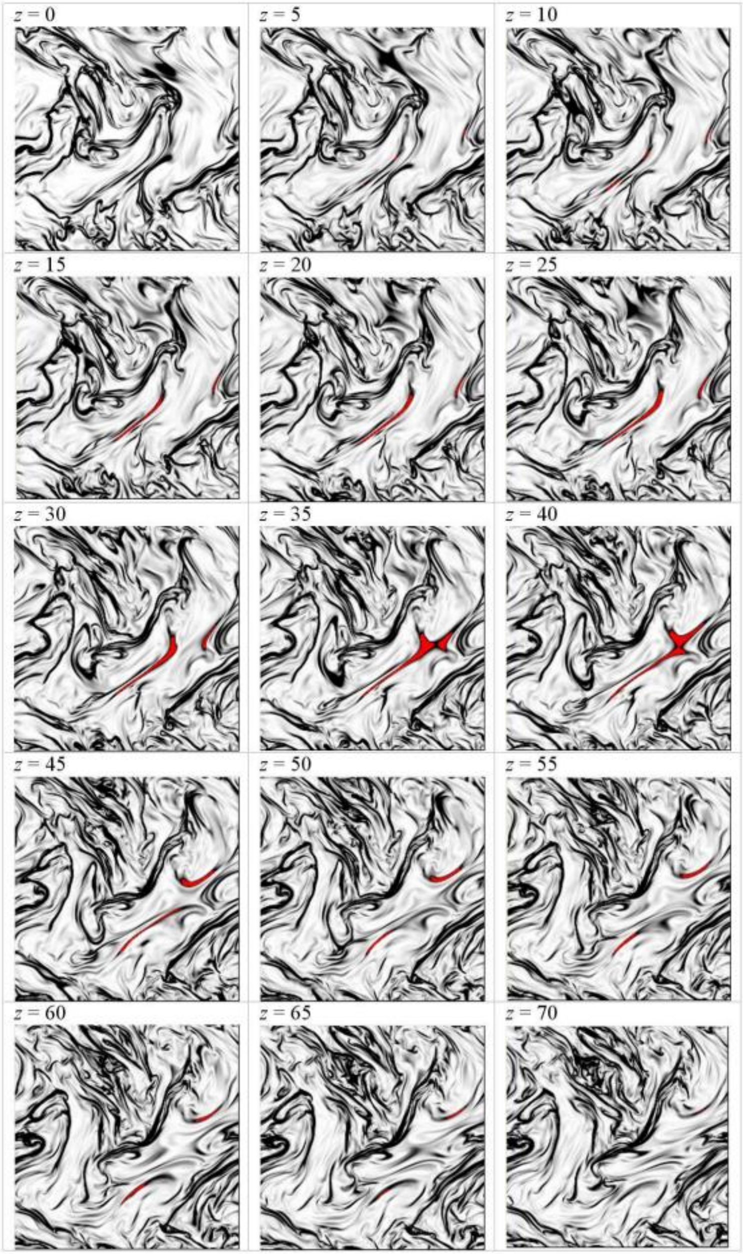
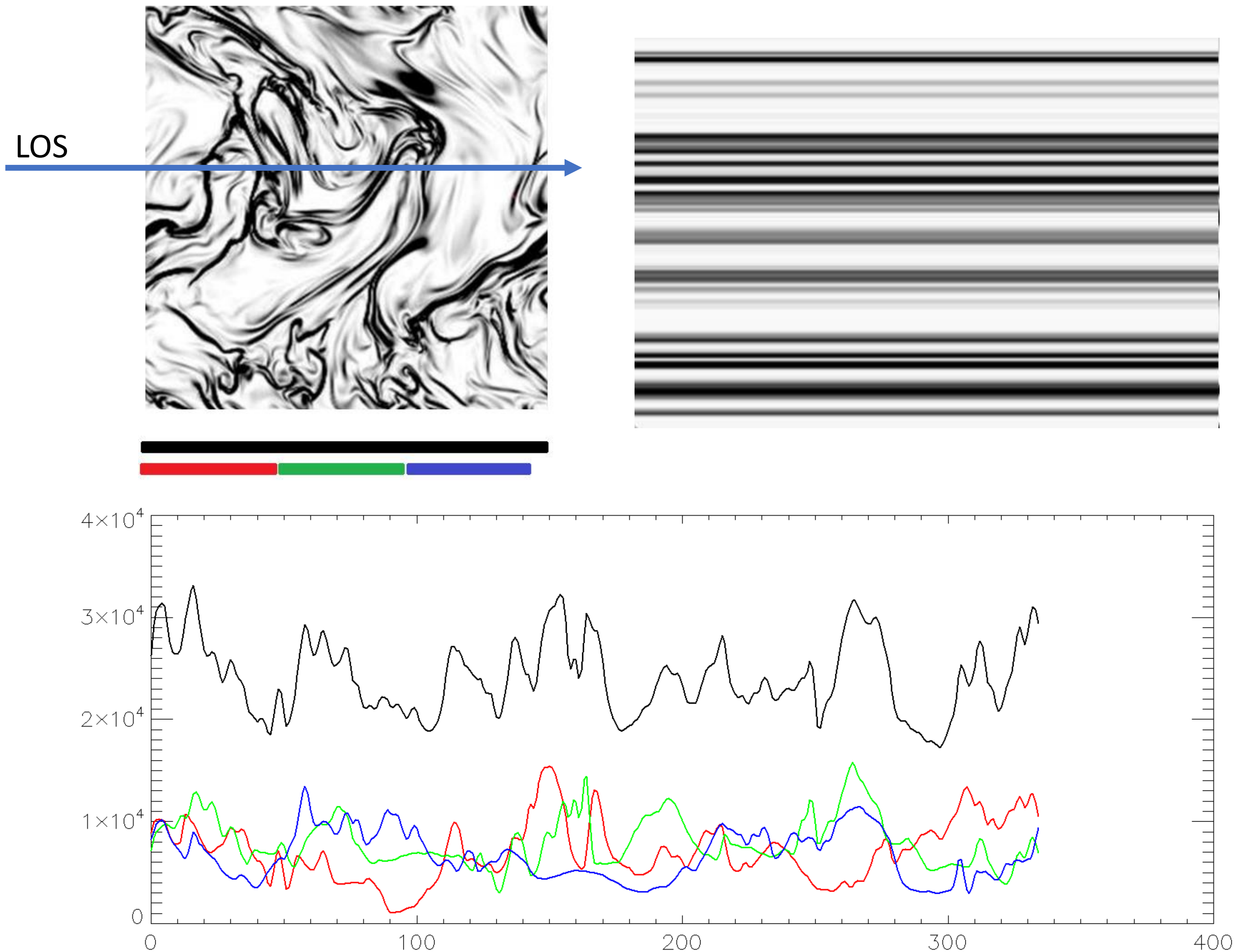
ABSTRACT

We present a systematic analysis of statistical properties of turbulent current and vorticity structures at a given time using cluster analysis. The data stem from numerical simulations of decaying three-dimensional magnetohydrodynamic turbulence in the absence of an imposed uniform magnetic field; the magnetic Prandtl number is taken equal to unity, and we use a periodic box with grids of up to 1536^3 points and with Taylor Reynolds numbers up to 1100. The initial conditions are either an X-point configuration embedded in three dimensions, the so-called Orszag-Tang vortex, or an Arn'old-Beltrami-Childress configuration with a fully helical velocity and magnetic field. In each case two snapshots are analyzed, separated by one turn-over time, starting just after the peak of dissipation. We show that the algorithm is able to select a large number of structures (in excess of 8000) for each snapshot and that the statistical properties of these clusters are remarkably similar for the two snapshots as well as for the two flows under study in terms of scaling laws for the cluster characteristics, with the structures in

Uritsky et al., PRE 2010






LOS
4×10^4
3×10^4
2×10^4
1×10^4
0
0
100
200
300
400

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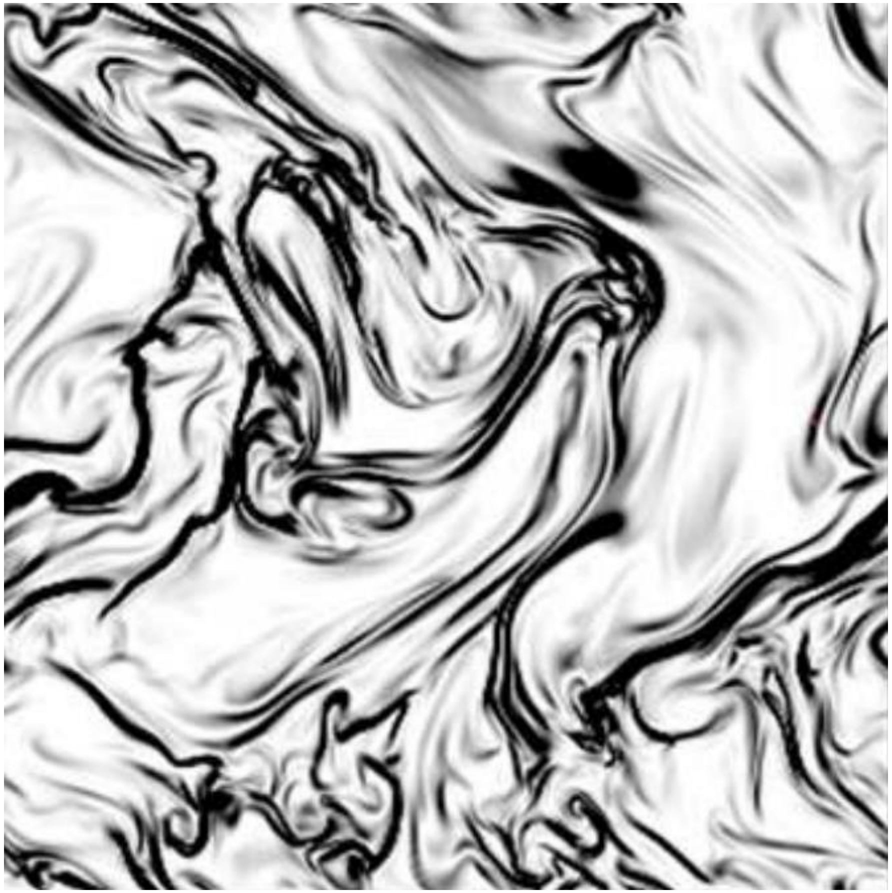
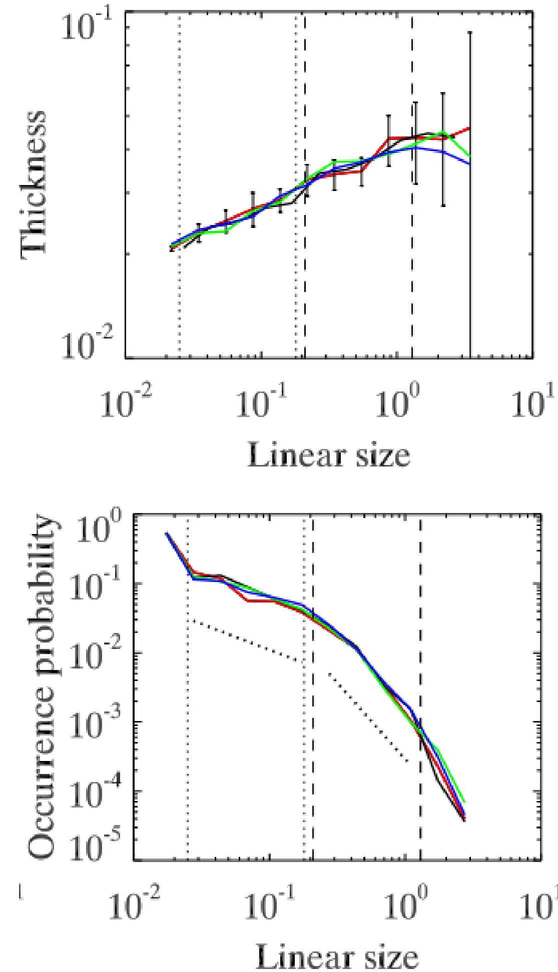
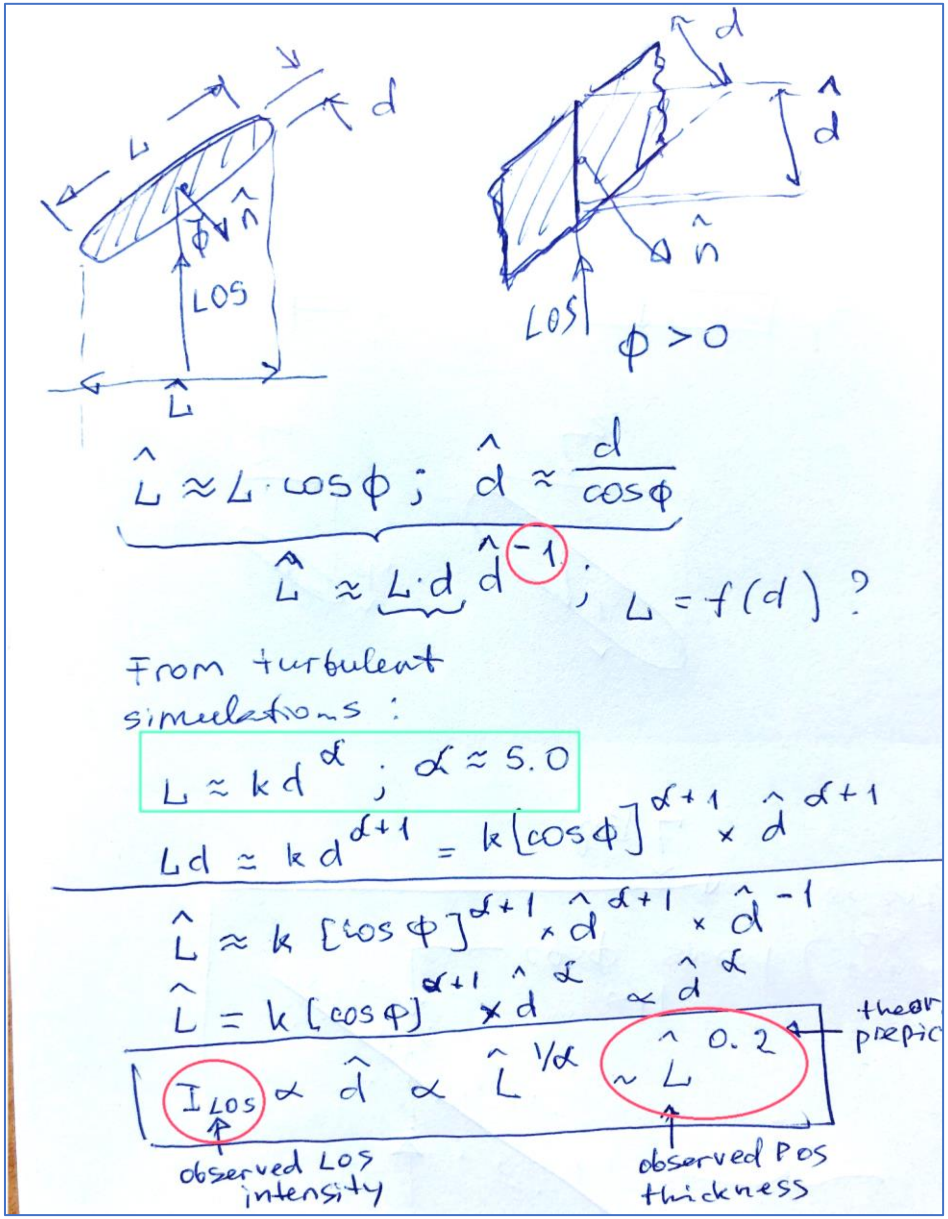
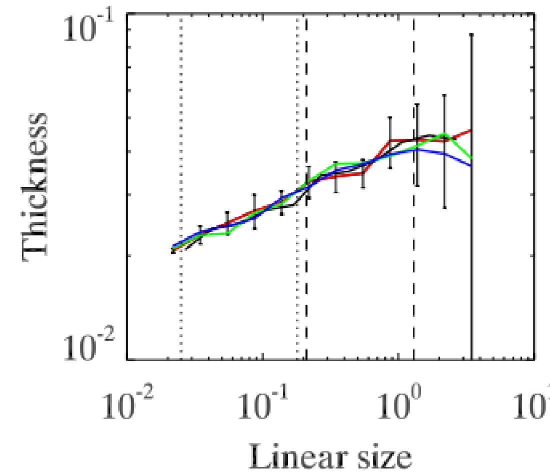


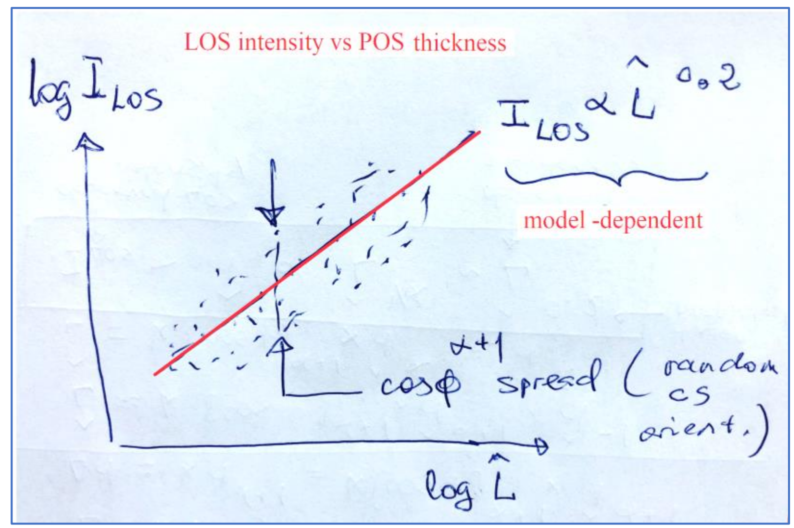


Observed signatures of randomly oriented CSs

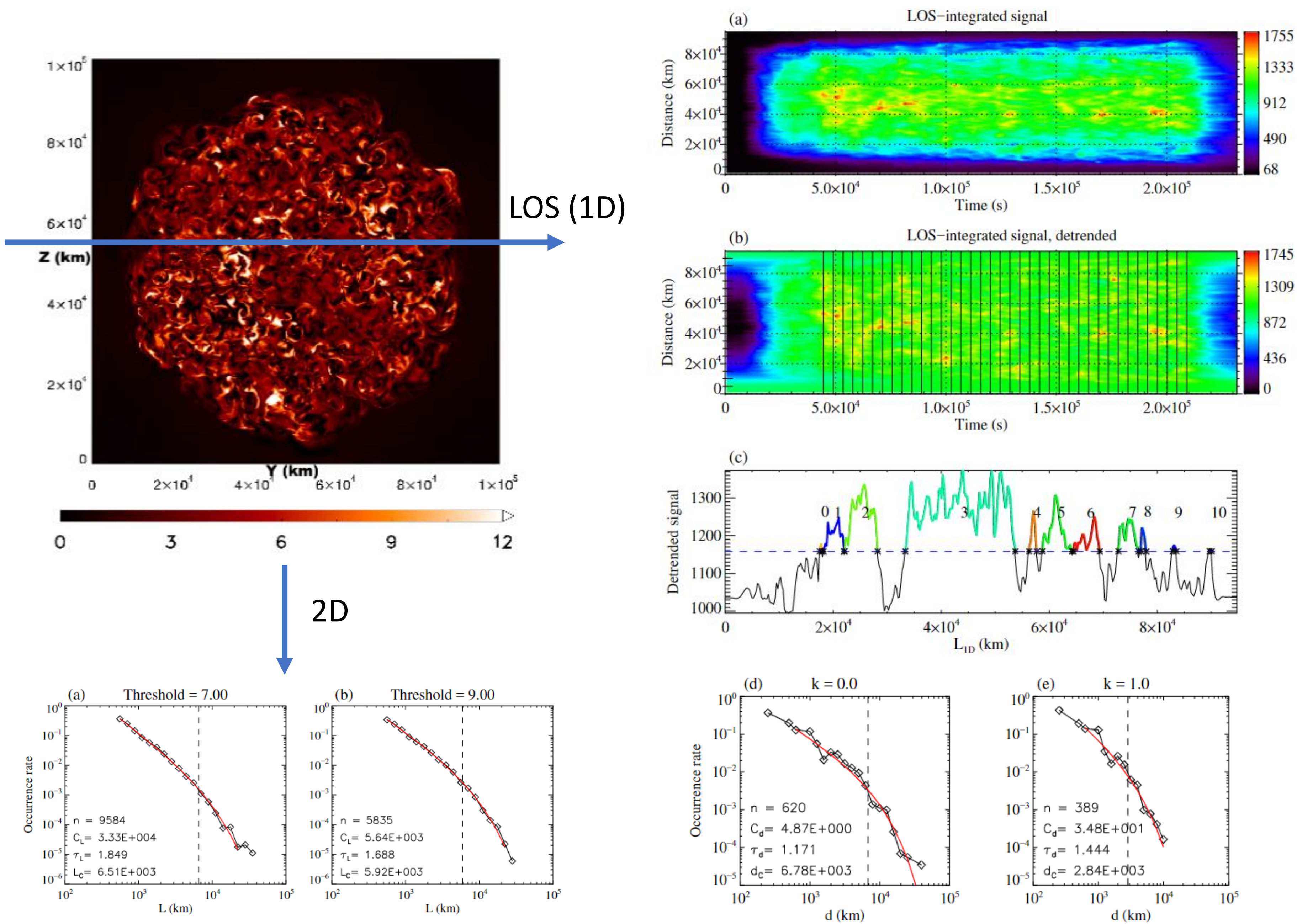




No overlapping CSs



Overlapping CSs: Monte-Carlo tests on MHD outputs.



LOS (1D)
2D
Z (km)
Y (km)
(a) LOS−integrated signal
Distance (km)
Time (s)
(b) LOS−integrated signal, detrended
(c)
Detrended signal
L1D (km)
(a) Threshold = 7.00
n = 9584
CL= 3.33E+004
τL= 1.849
Lc= 6.51E+003
L (km)
Occurrence rate
(b) Threshold = 9.00
n = 5835
CL= 5.64E+003
τL= 1.688
Lc= 5.92E+003
(d) k = 0.0
n = 620
Cd= 4.87E+000
τd= 1.171
dc= 6.78E+003
d (km)
(e) k = 1.0
n = 389
Cd= 3.48E+001
τd= 1.444
dc= 2.84E+003