Revealing the Lagrangian Skeleton of Solar Atmospheric Dynamics

S. S. A. Silva[1], V. Fedun[1], G. Verth[1], E. L. Rempel[2], I. Ballai[1]

[1] *The University of Sheffield, Sheffield, UK*

[2] *Instituto Tecnológico de Aeronáutica, São José dos Campos, Brazil*

Plasma flow mapping is crucial for better understanding essential aspects of the magnetohydrodynamics in the atmosphere of the Sun. The complex nature of plasma flows makes particle trajectory analysis sensitive to parameters, such as initial conditions and the number of particles. To address these problems, the Lagrangian Coherent Structure (LCS) framework, as being the most influencing material surfaces in a flow [1], is the most accurate and insightful tool to quantify and even forecast key aspects of the dynamics.

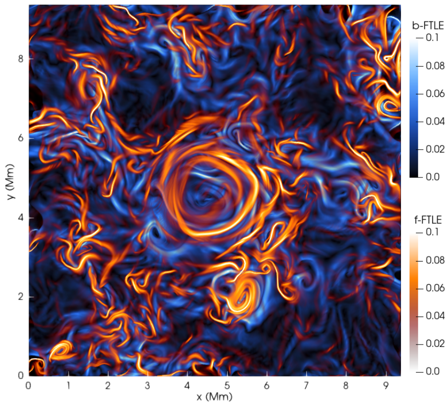

Figure 1: *Attracting (blue) and repelling (orange) LCS for electromagnetic energy transport in the quiet Sun.*

Various methods allow the identification of the different kinds of LCS, which may be attracting/repelling regions, Lagrangian vortices or regions with minimum shear. The distinct material surfaces separate regions of the flow undergoing different dynamics allowing a proper description of flow features and their impact on plasma turbulence. Although the detection of distinct types of LCSs in non-magnetic fluids is rather well developed (see, e.g. [1]), the number of studies on detecting LCS in plasmas is still limited. Recently, [2] indicated the detection of LCSs as the most promising approach to understand the plasma dynamics.

In this talk, we review the existing studies on the solar atmospheric LCS and present the developed methodologies aimed to describe essential solar features as kinetic and magnetic vortices [3, 4]. We also introduce tools we have designed to identify the sources and deposition location for electromagnetic energy. Figure 1 shows, for a simulated quiet Sun, the sources/deposition (in orange/blue) of energy at chromospheric heights. Finally, our talk addresses the use of LCS to forecast events such as active regions and flares.

References

[1] Haller, G. 2015, Annual Review of Fluid Mechanics, 47, 137 **10**, 10 (2015)

[2] Roudier, T., Švanda, M, Malherbe, J.M., Ballot, J., Korda, D., Frank, Z. A&A 647 A178 (2021)

[3] Silva, S. S. A., Fedun, V., Verth, G., Rempel, E. L., & Shelyag, S. 2020, ApJ, 898, 137

[4] Silva, S. S. A., Verth, G., Rempel, E. L., et al. 2021, ApJ, 915, 24