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Insights into the genesis and dynamics of the solar spicule forest: aided by MHD simulations and laboratory experiments

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Solar spicules are plasma jets that are observed in the dynamic interface region between the visible solar surface and the million-kelvin hot solar corona [1]. It is estimated that about million spicule jets are present at any given time over the entire solar disk. Due to their ubiquitous nature, they are believed to be a crucial candidate for conduiting mass and momentum flux to the solar wind, the primary driver of space weather [2]. Despite the paramount importance, several physical processes, such as the formation mechanism, the highly dynamic nature, their heating contribution to the solar corona, are not completely understood.

In the first part, we will present an intriguing parallel between the simulated spicular forest in a solar- like atmosphere and the numerous jets of visco-elastic (polymeric) fluids in laboratory experiments when both are subjected to harmonic forcing. In a radiative Magnetohydrodynamics (rMHD) framework, solar global surface oscillations are excited similarly with sub-surface convection. This process can solely assemble a forest of spicules that matches very well with the observed quantitative features of the Sun. Fascinated by the visual similarity between these highly non-linear astrophysical and laboratory systems, we further explore the mathematical and phenomenological similarities and present sufficient conditions to form a forest of jets on the Sun as well as in polymeric fluids[3].

In the second part, we shed new light on the morphology of spicular jets: drapery of plasma against the believed cylindrical plasma column structure by utilizing three-dimensional rMHD simulation data sets [4]. We will further describe various complex motions of spicules (spinning, swaying, splitting) from our 3D model, which are reported by several high-resolution observation facilities [5], e.g., Hinode and IRIS spacecraft. We detect multiple episodes of rotation amongst clusters of synthetic spicules, similar to their observed counterparts, due to interaction with hot swirling plasma columns. Interestingly, some of these swirling columns are also triggered by the spicular jets in our model. Finally, we will present the mass and energy flux contribution of spicules and swirls to the solar wind, supporting their role as a significant mass and momentum reservoir.

References

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