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Subject: **Report on Juraj Lörinčík's thesis**

Mgr. Lörinčík thesis focuses on the observational signatures of three-dimensional magnetic reconnection in solar flares. The manuscript introduces the physics of the solar corona (section 1), the properties of its eruptive activity (section 2), the 3D standard flare model predicting the dynamics of solar eruptions (section 3) and the data used (section 4). Then, it includes the 5 peer-reviewed papers produced during Juraj Lörinčík's thesis, accompanied by individual summary (section 5) and the conclusion with the perspectives of future work in section 6. The manuscript is well organised and presents all necessary elements. The major results are clearly exposed and synthesised in each section and in the conclusion.

The first study of this thesis aimed at measuring velocities of the apparent slipping motions of bright kernels along the flare ribbons. Such motions result from the slipping reconnection (a pure 3D reconnection regime) and are predicted by the 3D standard flare model. This study shows that the speed is higher in weaker B-field regions. By computing the N-factor in the 3D standard flare model, Lörinčík et al., 2019 find that the slipping velocity is higher where the N-factor is high too. This work provides a strong support to the dynamical properties of solar eruptions predicted by the 3D flare model.

The second and third paper focus on the manifestation of specific reconnection geometries predicted by the 3D standard flare model. By processing the EUV images of selected solar eruptions, J. Lörinčík extracted and visualised the strands composing the flare loops and the erupting filament legs. In those two papers he shows that during solar eruptions, footpoints of the identified structures are swept by the solar flare ribbon hooks. According to the 3D standard flare model, such behaviour indicates a new and specific geometry of the field lines that reconnect during the flare: the ar-rf reconnection (the erupting flux rope and the overlying arcades reconnect and form a new flux rope field line and a flare loop). In both studies, some or all field lines involved in the ar-rf reconnection geometry have been identified, providing additional evidences of 3D magnetic reconnection in solar flare and confirming for the first time this new purely 3D reconnection geometry.
In the fifth paper, J. Lörinčík focused on flare loops displaying a saddle-like shape in five well-studied solar flares. Similarly to his previous studies, he shows that the flare ribbon

hook swept the overlying arcade footpoints indicating that ar-rf reconnection geometry is taking place. The morphological analysis of the flare loops suggests that the reconnected field lines from the ar-rf reconnection geometry are longer and more inclined that the flare loops formed by the aa-rf reconnection. By studying five different events, he proposed that such observation of saddle-like shape flare loops could be a generic properties of solar eruptive events, and therefore being consistent with the 3D standard flare model.

Showing that the EUV flare loops and flare ribbons observed during solar eruptive events result from the ar-rf reconnection geometry composes the core of this thesis work. As specified later in the report, this work provides essential insights for the solar physics community. While the observational analysis performed in this thesis are very convincing, I'm wondering what are the limits of the performed analysis based on the identification of the field lines and their associated footpoints? In numerical studies, the line-tying condition at the lower boundary allows us to follow magnetic connectivity of field lines from fixed footpoints. How does it transpose to the EUV observations knowing that in the real Sun there is motions at the solar surface? How confident can we be that the same field lines and footprints have been followed before and after the reconnection?

In the fourth paper, Mgr. Lörinčík shows for the first time that plasma outflows are observed in the stretching CME's leg. The spatial and temporal properties of the outflows agree with the standard mechanism of coronal dimming based on the plasma depletion along open magnetic field. During the studied event, the flare ribbon hook evolution suggests that the ar-rf reconnection geometry takes place. However, it only extends the region of the core dimming and is not involved in the outflows acceleration. This study provides the first evidence that plasma outflows in a CME's leg act to deplete the plasma in a core dimming.

According to the magnetic field measurement, small scale magnetic dipoles are present inside the flare ribbon hook where the CME's leg is anchored. This suggests that magnetic reconnection could occur between the magnetic field of the CME's leg and the loops associated with the small magnetic dipoles. The event studied in this paper is extremely complex and I may have missed some subtleties, thus I'm curious to understand why magnetic reconnection between the CME's leg and the small loops inside the hook has not been considered as a potential mechanism to accelerate the outflows ?

This thesis work is of a great interest for the solar physics community. Indeed, since the last 15 years 3D models have been developed to understand solar flares and eruptions. Such 3D models provided new insights on the dynamics of the coronal magnetic field that can explain the observations. However, due to the complexity of the dynamics of solar eruptions, it has been extremely difficult to identify observational signatures of the 3D magnetic reconnection predicted by the 3D models. Mgr. Lörinčík thesis brilliantly succeeded in extracting the relevant indicators proving that the 3D standard flare model explains the solar eruptions. His work will have a high impact for the future advances in solar physics.

He undoubtedly created new and original results that should be widely exploited. His expertise in extracting the relevant signal from EUV observations is unique and of high value for the future of our community. Identifying, locating and following flare loops and erupting structures is critical to understand the dynamics of solar eruptions. It is also remarkable that he doubled his observational analysis skills with a deep understanding of the 3D standard flare model. Such synergetic approach will allow him to produce major breakthroughs in the field.

Finally, I would like to congratulate Mgr. Lörinčík for this excellent thesis and I look forward to his defense.

Yours Sincerely,

Sophie Masson