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To whom it may concern,

I hereby state that I have thoroughly revised the doctoral thesis “Interaction between solar convection and magnetic fields” by Ms. Marta García Rivas. This thesis work is a compilation of four scientific works (one presented as an appendix) that study fundamental aspects of solar magneto-convection in active regions using unique observational data from multi-instrument campaigns at high spatial, spectral, and temporal resolutions.

The thesis is well-organised and methodologically sound, beginning with a comprehensive review of the theoretical background on the interaction between solar magnetic fields and the convective plasma. The transition from theoretical discussions to data analysis is smooth, and the observational data from various instruments as well as the employed sophisticated data analysis tools are all properly described in sufficient detail. The author demonstrates a solid understanding of both the theoretical aspects and the practical challenges of solar observation. The discussion of results is clear and concise, with appropriate consideration given to previous work in the field.

In my opinion, Marta García Rivas’ thesis is a significant contribution to the field of solar physics. It presents new scientific results regarding the magnetic properties of solar pores, the decay process of a sunspot, the formation of penumbral filaments, as well as the thermodynamics of the solar chromosphere during a solar flare. All these topics are fundamental problems in solar physics and the findings presented in this thesis substantially contribute to a better understanding of the solar magnetism. Some of the novel scientific contributions that emerge from Marta’s thesis are:

1. A Critical Vertical Magnetic Field in the Boundary of Solar Pores
The existence of a critical vertical magnetic field (Bver) at the boundary of solar pores. This result parallels the observations made by Jurčák et al. (2018) for sunspots, but with a weaker Bver. The finding that pores also have a threshold magnetic field at their boundaries expands our understanding of solar magnetic fields and contributes to the empirical laws that govern solar magneto-convection by demonstrating the importance of the critical value of Bver on the stability of magnetic structures such as pores and sunspots against the destabilising effects of the magneto-convective motions in the surroundings.

2. Stability and Evolution of the Umbral-Penumbral Boundary in Decaying Sunspots
Another key contribution is the detailed study of the evolution of the magnetic boundary during the decay of sunspots. The thesis builds on earlier work that identified a critical vertical magnetic field necessary for the stability of sunspots and expands this understanding by tracking the weakening of Bver during sunspot decay. This provides valuable insights into the final stages of the sunspot evolution and the interaction of the magnetic field with the surrounding convective flows, showing that the vertical fields affect the convective mode, while the horizontal fields shape the convective cells, as stated by Chadrasekhar (1961).

3. Physical Properties during the Onset of a Penumbra Formation
The thesis also presents the novel finding that the formation of penumbral filaments (and the consequently onset of the Evershed flow) does not depend on the pre-existing magneto-convective modes, as either a bi-directional flow in elongated granules, a counter-Evershed flow in a transient filament, and a granular flow pattern have all been identified triggering the penumbra formation. This is a departure from previously held beliefs that suggested

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a direct relationship between the underlying magnetic structure and the filament formation. This has important implications for the study of the transition between pores and sunspots, offering new insights into how penumbra formation occurs around a growing sunspot without being dictated by the type of magneto-convection that was present before filament formation.

4. Evolution of the Chromospheric Temperature During a Solar Flare
These findings provide valuable empirical data for improving models of chromospheric heating during flares. The multi-wavelength approach enriches our understanding of energy dissipation in the solar atmosphere and the role of continuum enhancements, which are still poorly understood in small-scale flares. This work has implications for improving solar flare models, particularly in relation to space weather forecasting.

Overall, Marta García Rivas' thesis challenges existing models and provides a deeper understanding of solar magneto-convection and the evolution of pores and sunspots. With the present work, she clearly shows a creative approach to solving these complex problems, and combined with a thorough and rigorous analysis, proves her ability for independent and innovative scientific work. The author also demonstrates clear originality throughout her research. She successfully identifies gaps in the existing literature, such as the under-exploration of solar pores in comparison to sunspots, and addresses them with new observations and analyses. Her contribution to the understanding of the vertical magnetic field and penumbral filament formation is not only novel but also valuable for future research in solar physics.

Likewise, the main results presented in this thesis have potential applications in neighbouring fields, since they not only indirectly contribute on the prediction of solar activity, which at the same time helps improving models for space weather forecasts, but also the thesis has a broader impact on fields such as Magnetohydrodynamics and stellar astrophysics.

To conclude, I would like to explicitly state my positive evaluation on the provided work. If you have any further questions or concerns regarding this report, please do not hesitate to contact me.

Sincerely,

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