

Jury Member Report – Doctor of Philosophy thesis.

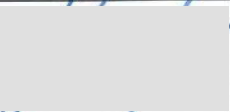
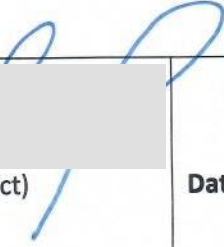
Name of Candidate: Galina Chikunova

PhD Program: Engineering Systems

Title of Thesis: Coronal dimmings associated with coronal mass ejections: evolution, lifetime, and relation to the directivity

Supervisor: Associate Professor Tatiana Podladchikova

Name of the Reviewer: Anatoli Petrukovich

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	 	Date: 13-11-2023
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The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

- **Brief evaluation of the thesis quality and overall structure of the dissertation.**

The doctoral thesis "Coronal dimmings associated with coronal mass ejections: evolution, lifetime, and relation to the directivity" submitted by Galina Chikunova is a piece of high quality research. Primarily it

discusses how coronal dimmings can be used as a diagnostic tool for early evolution of coronal mass ejections (CMEs) from the Sun using multipoint observations from NASA's SDO and STEREO missions. The thesis has a logical structure, starting with Chapter 1 - Introduction to Heliophysics, succeeded by dedicated chapters on CMEs (Chapter 2) and coronal dimmings background information (Chapter 3). Chapter 4 presents the comprehensive developed methodology for the dimming analysis. The next chapters with specific results cover statistics on the CME-dimming relationship (Chapter 5), dimming lifetime (Chapter 6), and the relation between dimming morphology and the direction of the associated CME/filament (Chapter 7). The manuscript effectively integrates results of several separate studies, cohesively linked by shared methodologies and overall goal. In the Conclusions section (Chapter 8), the thesis revisits the initial research questions, discussing the results as well as providing insights for future research.

- **The relevance of the topic of dissertation work to its actual content**

The declared topic of the dissertation work is in agreement with its actual content. CMEs are the main sources of strong geomagnetic storms and Space Weather disturbances, having a significant impact on space and ground-based infrastructure. However it is challenging to trace an early evolution of CMEs (in particular the Earth-directed ones), as usually they are detected only at a developed stage in the field of view of near-Earth coronagraphs. As coronal dimmings are effectively CME footprints in low corona, they can be observed during the entire CME evolution from pre-eruption to the post-event recovery. Profound understanding of dimming - CME relationships and novel methods of dimming analysis open a great potential for diagnostics of birth and early CME evolution, mass loss, speed, propagation direction, as well as solar corona recovery. Thus, the thesis research questions on how coronal dimmings can be used to estimate CME properties are all meaningful: q1) relation to CME mass and speed (how can we use dimmings to estimate the mass and speed of CMEs?); q2) dimming lifetime (how and when does the solar corona recover after a CME eruption?); q3) relation to CME direction (how is the evolution and morphology of dimmings connected to the early propagation direction of CMEs?)

- **The relevance of the methods used in the dissertation**

The thesis introduces novel and relevant methods for a detailed analysis of coronal dimming and their link to CMEs. First, the extensive statistical multi-viewpoint analysis of a large sample of well observed dimmings/CMEs, which included the development of automatic detection and segmentation methods, full characterizations of dimming parameters and their relations to prime parameters of the associated CMEs, revealed distinct correlations between dimming area and CME mass, as well as between dimming brightness and maximal CME speed. A particular focus was on the CME and dimmings observed off-limb, which is relevant for future L5 space weather missions as well as early space weather predictions. Second, the thesis presents effective methods for estimating the dimming lifetime. And finally, the study introduces an original hypothesis that coronal dimming not only indicates the onset of an eruptive event, but also its evolution is linked with an eruptive filament and initial direction of a CME propagation. This hypothesis was confirmed by a detailed case-study, which included the development of a method to estimate the dominant direction of the dimming evolution, determination of the segmented dimming area and 3D reconstruction of the white-light CME by graduated cylindrical shell modeling (GCS). The results revealed that the dominant propagation of the dimming growth reflects the direction of the filament, while the overall dimming morphology strongly aligns with the inner part of GCS croissant located between the two footpoints, which allowed to link the 2D dimming with the 3D CME bubble. These outcomes were used as a foundation for the further development of methods to derive 3D CME direction close to the Sun in one of the co-author papers and are of high importance for space weather predictions.

- **The scientific significance of the results obtained and their compliance with the international**

level and current state of the art

The methods, findings and outcomes of the thesis, suggesting to use the coronal dimmings for the early diagnostics of coronal mass ejections, their speed, recovery of solar corona after eruption are important from both fundamental and applied point of view for Solar Physics and Space Weather predictions. The results obtained are on a high international level and in line with the current state of art. It is confirmed by a number of publications in high-impact international journals and presentations at top international conferences, as well as support of the studies by the Russian Scientific Foundation grant.

- **The relevance of the obtained results to applications (if applicable)**

These results would be of interest for Space Weather applications, enhanced Space Weather forecasting, predictions of arrivals and potential impacts of CMEs (in particular the Earth-directed ones).

- **The quality of publications**

The thesis resulted in 2 first-authored papers and 4 co-authored (2 published, 2 under review) papers in high-impact international journals.

The summary of issues to be addressed before/during the thesis defense

I have several comments below which may be addressed.

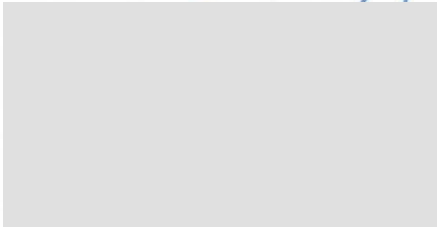
- 1) The introduction section would benefit from more precise indication of the problem statement, novelty, relevance, and positions advocated for defense.
 - 2) To better check the content of Chapter 1. Some of the content seems to be written in a rush, etc. such as the "four million tons of energy" typo. Enhancing the scientific content of this chapter by also incorporating additional references is advised.
 - 3) On page 23, the citation to Figure 1-7 could be inaccurate.
 - 4) The final paragraph on page 34 is lacking clarity and may benefit from a more precise articulation of concepts.
 - 5) On page 47, the usage of "close relationship" is identified as non-scientific terminology.
 - 6) The reference to Figure 5.9 is absent on page 114.
 - 7) Chapter 7 presents an event dated October 28, 2021, which is initially referenced. But later it is followed by the introduction of an additional event from 2011, which can be confusing for a reader.
 - 8) It is recommended that a more explicit indication of achievements and emphasis on novelty be integrated for the conclusions in each chapter. While external references can validate results, a balanced approach that underscores the originality of the results is encouraged.
 - 9) Chapter 5 exhibits a good example of results and conclusions representation. Similar enhancements can be applied to improve other chapters. Also, more comprehensive and generalized chapter conclusions are expected in the dissertation's main conclusion.
- I think that the issues above do not decrease the scientific quality of the thesis and Galina Chikunova deserves to be awarded with Skoltech PhD degree.

Provisional Recommendation

I recommend that the candidate should defend the thesis by means of a formal thesis defense

I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report

The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense



A. R. Petrukovich.