SHORT SUMMARY AND REVIEW OF THE DISSERTATION

Reviewer: Pavel Novák

Name of the candidate: Kurosh Karimi

Degree: Doctor of Philosophy

Title of the dissertation: Gravity and magnetic fields of small planets

Evaluation of the content

The dissertation is focused on the use of gravity and magnetic data in the research of the Earth and similar (small) planets in the Solar System. On four specific cases, each of which was published in a high-quality scientific journal, the candidate demonstrates the use of selected functionals of the potentials of the static gravitational and magnetic fields of the planets to confirm (or refute) specific hypotheses regarding the presence of water, location of impact craters or the estimation of the depth of shallow mass density anomalies. Research objectives in all four cases are well defined with new findings obtained for all of them.

The dissertation has 82 pages (without a long list of references) and is divided into eight chapters. Chapter 2 introduces the topic and summarizes the current state, Chapter 3 contains the basics of the methodology and describes the input data, Chapters 4-7 contain four research articles published in *Scientific Reports*, and Chapter 8 summarizes the obtained results and insights, and outlines several recommendations for future research. As will be clear from the text below, some chapters (especially 3 and 8) do not quite live up these expectations.

Chapter 3 has 10 pages. As one would expect, this chapter should set the stage for the four research articles that follow. It should be explained how they contribute to the overall topic of the dissertation (i.e., gravitational and magnetic fields of small planets). This part of the dissertation should discuss briefly and concisely the topic while referencing the four articles. I must admit that in my view this chapter fails to bridge the four problems discussed in the research articles. Its text is also typed with some flaws that are discussed below. Although I have nothing against dissertations based on compilation of several research articles, I would expect that the dissertation would contain a short but concise overview of the topic with details described in the appended publications.

Chapters 4-7 contain four research articles, all published in the high-quality multidisciplinary journal *Scientific Reports* (currently IF 3.8, Q1 among multidisciplinary journals). In three cases, the candidate is the senior author. Their content including hypotheses under investigation and main finding are summarized per partes in the dissertation. As all articles were all published in the high-quality journal with high standards of peer review process, my evaluation does not cover their content. I will concentrate mainly on Chapters 3 and 8.

Comments and/or questions

Usually, I divide my comments between those of major and minor importance; however, this time I will just point out some problematic issues in the text.

Title: It does not correspond to the content of the dissertation. Gravitational and magnetic fields are used for investigating selected problems related namely to detection of anomalous mass densities within small planets. In the current version of the title, one would expect both fields to be recovered or modelled from available observations.

Structure: The dissertation could have the common structure (i.e., introduction, review of the state-of-the-art, formulation of research hypotheses/problems, explanation of methods and description of input data, discussion of numerical experiments, summary of results and conclusion) with the four research articles in the appendix.

Page XIII: I do not like alternating the terms functional and aspect. It is obvious that the author is using various functionals of the gravitational and magnetic potentials, all functions of 3D position (static fields). I do not understand why, e.g., topography (3D mass density distribution?) is referred to as a functional (of what) derived from independent components of gradient tensors.

Section 1.2, line 1: The terminology is sometimes used in a strange way. For example, what does it mean that "potential field data is ... method ..."? There are more such examples in this section.

Section 1.3: It seems to me that the only input data used in the dissertation are global models of external static planetary gravitational fields represented by expansion of their potentials into spherical harmonic series, global digital elevation and magnetic models. Models based on harmonic series are often arbitrarily truncated, although it is known that complete models should be used (only the full series represents the respective function correctly). Some of the models are not explained correctly, e.g., EIGEN-6C4 was estimated by combining satellite (GOCE and SLR) and surface gravity data.

Page 11, Table 1: Not all the parameters used later in the equations are defined in this table. Some parameters are defined in a strange way (e.g., Cartesian components of the gravity field), some are ambiguous (harmonic coefficients related to the reference ellipsoid), some are missing (what is the meaning of the parameter *B?*) Why do you define (and use) so many Cartesian systems (geocentric, LNOF, source-oriented LF)?

Page 12, Eq. (1): The harmonic series is limited in degree that likely reflects available global gravitational (geopotential) models. While the maximum degree is always limited, the lower degree is equal to zero in all models found for example in ICGEM. The centrifugal potential can be also expressed using Legendre functions to be consistent with the harmonic series of the gravitational potential. The series has a form that is particularly useful in satellite dynamics (zero degree and order term is GM/r instead of standard GM/R).

Page 12, Eq. (3): The concept of the disturbing potential should be explained. The series should contain cosine harmonic coefficients reduced for the normal field, see Eq. (4). The normal (reference) field should be defined (implicitly it is a field of Somigliana-Pizzetti type, i.e., rotationally symmetric field generated by an equipotential biaxial ellipsoid). This field is used in geodesy but as it does not imply any internal mass density distribution, it could be less useful in geophysics.

Page 12, Eq. (4) and below: The definition of reduced harmonic coefficients implies the normal field as defined above. One could add that the coefficients in the series expansion of the normal potential can be simply computed using analytical formulas and four defining parameters (sometimes called Stokes parameters).

Page 12, Eq. (5): The gradient tensor is symmetric with five independent (and six unique) components in continuous and mass-free space. Why do you use the LNOF to define its components? Maybe some references could be added to Eqs. (7)-(12) and below. As you state on Page 14, EGMs are used to evaluate the components numerically. One could use the geocentric spherical (or even Cartesian) system.

Section 3.3: I am not quite sure I entirely follow the derivation of the full gravity vector (and components of the GGT) from its modulus (as this value is measured). Is it possible without supplying other observations (e.g., deflections of the vertical)? Do you use this method in your studies? Note that components of the gravitational vector are measured directly by vector gravimetry (namely aerial) and components of GGT are measured with satellite gradiometry (albeit not all components were measured with the same accuracy). Also, in the line below Eq. (15): m = ... and n = ... are unit vectors (orthogonal basis vectors in the Cartesian coordinate system)? Similar comments would apply to Section 3.4.

Sections 3.5-3.13 (Section 3.11 is Section 2.12 in the text): There are several short sections that describe the properties and various manipulations of the GGT and MGT components. It is not explained where, why and how these operations are applied. These parts of the dissertation are not very useful, they seem to be written at a pace, not carefully enough.

Chapters 4-7: These chapters contain four research papers published in Scientific Reports, Springer's respected multidisciplinary journal. They were peer-reviewed before publication and do not need to be reviewed again. One might argue that some of the findings are speculative, but that is often the nature of planetary research, where independent data is non-existent or scary. The future will decide. The candidate's contribution to all articles is essential, in three cases he is the lead author. The contribution of all authors is well described in the articles.

Chapter 8: This chapter is weak in my opinion. It contains general statements and potential research objectives are summarized in four bullet points. How they relate to the findings of the dissertation is unclear (or unexplained). The summary of the dissertation is then completely missing (the main findings from the four research articles are summarized elsewhere).

Summary

The dissertation contains some issues; however, they do not underestimate the research presented in the four research articles. It is their content that allows me to formulate my recommendation below.

Recommendation

Through research conducted during his studies at the Charles University in Prague, the candidate has proven that he is qualified to obtain a PhD in the field of applied geophysics. The main results of his research have been published in several impact-factor journals, of which he is a co-author. The texts, which form one part of the dissertation, also demonstrate his abilities in the field of scientific cooperation important for allocating research funds.

Thus, I evaluate the submitted dissertation positively and recommend Mr. Kurosh Karimi to be awarded the PhD degree from Charles University in Prague.

In Pilsen, 11 September 2024

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prof. Pavel Novák