Posudek práce

předložené na Matematicko-fyzikální fakultě
Univerzity Karlovy

☐ posudek vedoucího ☒ posudek oponenta
☐ bakalářské práce ☒ diplomové práce

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Název práce: Kernel integrals in time–distance helioseismology
Studijní program a obor: Physics, Astronomy and Astrophysics
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Odborná úroveň práce:
☐ vynikající ☒ velmi dobrá ☐ průměrná ☐ podprůměrná ☐ nevyhovující

Věcné chyby:
☒ téměř žádné ☐ vzhledem k rozsahu přiměřený počet ☐ méně podstatné četné ☐ závažné

Výsledky:
☒ originální ☐ původní i převzaté ☐ netriviální kompilace ☐ citované z literatury ☐ opsané

Rozsah práce:
☐ veliký ☒ standardní ☐ dostatečný ☐ nedostatečný

Grafická, jazyková a formální úroveň:
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Tiskové chyby:
☐ téměř žádné ☒ vzhledem k rozsahu a tématu přiměřený počet ☐ četné

Celková úroveň práce:
☐ vynikající ☐ velmi dobrá ☒ průměrná ☐ podprůměrná ☐ nevyhovující

Slovní vyjádření, komentáře a připomínky oponenta:
Bc. Chmúrny's dissertation endeavours to assess the reliability of critical parameters in local time–distance helioseismology, particularly focusing on the sensitivity kernels associated with horizontal flows. Helioseismology utilises properties of solar oscillations induced by acoustic and surface gravity waves generated by vigorous convective motions. The principle of time–distance helioseismology lies in measuring wave phase travel times τ, which are sensitive to local perturbations in plasma parameters $\mathbf{q}$, especially to vector flows and sound-speed perturbations. Sensitivity kernels, derived from a background solar model, serve as conversion factors between travel times and plasma parameters. The proposed methodology involves introducing a constant perturbation into observed Dopplergrams. The resulting travel time shift, owing to this constant perturber, exhibits a linear dependence on the volume integral of the corresponding sensitivity kernel. This integral, calculated as a slope of the $\tau(q_i)$ dependence, offers a model-independent constraint for the full 3D model-dependent sensitivity kernels utilised in time–distance helioseismology.

The dissertation comprises five chapters introducing and clarifying the methodology, during which the author familiarises readers with fundamental concepts and innovative methodologies. The initial chapter provides an overview of solar interior structure, while the subsequent chapter delves into dispersion relations of studied waves and describes data filtering techniques. In the third and fourth chapters, the author introduces time–distance helioseismology and presents their novel approach to sensitivity kernel testing. The fifth chapter elaborates on the input data and primarily discusses the employed pipelines.

The results chapter elaborates on the data and methodology, alongside mode-unspecific statistical analyses comparing model-dependent and model-independent kernel integrals. In the discussion chapter, the author briefly summarises the results and explores the implications of specific travel time measurements on the outcomes.

The findings of this dissertation are undoubtedly worthy of publication, yet require further refinement and detail. Sensitivity kernels are dependent on a background solar model and the level of approximation. The author briefly touches upon several different approximations, however, the one used remains unspecified, as does information about the background model. The assertion that "differences between these two travel times are most sensitive to the flows" differs from the explicite statement "we used the difference of these two travel times to test flow sensitivity kernels". Travel times encompass various definitions, and the one utilised in the dissertation is initially mentioned towards the end of the discussion chapter.

The pivotal result of this dissertation is summarised in Fig. 6.6, illustrating the accuracy of model-based kernel integrals for ridge filters, with a possible minor systematic shift for p1 modes. However, the model-based kernel integrals for phase-speed filters are entirely inaccurate for at least half of the 11 filters. This finding is crucial, given the extensive use of phase-speed filters in many past inversions.

In the discussion, the author interprets the linear slope fitted for all geometries as a result of the ridge filters only. The actual slope for the ridge filters is likely very close to the presented one, as the entire fit is governed by the surface f mode, which is trustworthy. Additionally, the author discusses the overall correlation coefficients for ridge filters (again governed by the f mode) and phase-speed filters. However, the assertion that the high correlation solidifies the good results for the ridge filters, and vice versa for the phase-speed filters, is incorrect for two reasons. Firstly, a visual inspection of Fig. 6.6 suggests that most modes exhibit high correlation coefficients when computed separately, but this does not support the conclusion that all the filters are acceptable. Secondly, the correlation coefficient is a meaningless quantity in a one-to-one match test. A set of kernels that are 10x higher than expected may still have a high correlation coefficient.

Overall, this work could have a significant impact on future and past models. It's important to note that incorrect volume integrals make the full 3D kernels unusable. Unfortunately, the result and discussion chapters are incomplete and contain some incorrect implications. A detailed analysis of individual filters could be beneficial for those conducting inversion modelling, potentially improving their results by excluding certain observation geometries.

Případné otázky při obhajobě a náměty do diskuze:
Why did you sample the injected velocities randomly?

Is it necessary to neglect the mean realisation noise? Can it be added to the background travel time?

In the discussion, you tested your tracking pipeline against LCT. As you use a constant shift, did you try, for example, phase correlation?

You used the GB02 travel time definition for the final tests. This definition is based on the match of the reference and observed cross-covariance at every point, but the matching procedure sometimes fails due to noise. How did you deal with this?

In Fig. 6.1, you present the mean travel times versus injected velocity for all eight observations. The slopes for these are comparable, but the constant term is different. You interpret it as an effect of irregularities in solar rotation. It seems that the variation in the constant term is almost zero for surface modes and increases for modes that penetrate deeper into the convection zone. Do you have an explanation for this depth dependency, or is it true only for the three plotted modes? Do you think this could be caused by some large-scale perturbations at larger depths, e.g., due to depth rotation profile?

What does it mean that the modelled cross-covariance is not precise enough?

Do you want to continue in helioseismology?

Práci
☒ doporučuji
☐ nedoporučuji
uznat jako diplomovou.

Navrhuji hodnocení stupněm:
☐ výborně ☒ velmi dobře ☐ dobře ☐ neprospěl

Místo, datum a podpis oponenta: Ondřejov, 16.05.2024