1351 / Cebry et al. / Heterogeneous high frequency seismic radiation from complex ruptures

Round 1

Reviewer 1:

The submitted manuscript ‘Heterogeneous high-frequency seismic radiation from complex ruptures’ by Sara Cebry and Gregory McLaskey investigates the influence of a geometrical heterogeneity, generating a normal stress ‘bump’ along the fault, on the radiated frequency of laboratory frictional ruptures. The experimental setup and procedure are already presented in their previous work (Cebry at al. 2023) where they show that the presence of a normal stress bump along the fault can be responsible for a more complex rupture style (generating either partial ruptures, ruptures slowing down and re-accelerating right after the bump, etc..). The submitted manuscript highlights the effect of such a normal stress bump on the frequency seismic radiation. In particular, they highlight how the high-frequency radiation content is larger in the case of complex ruptures than it is for continuous ruptures. Moreover, while continuous ruptures emitted spatially uniform high-frequency radiation, complex ruptures showed spatially heterogeneous radiation, with a paek in correspondence to the stress heterogeneity. The authors propose local stress heterogeneities as a possible cause of the observed near-fault peak ground acceleration (PGA) variations.

The manuscript is well-written, with a clear methodology and well-designed figures. The results are well presented and supported by the data. The considerations and conclusions are articulated effectively. I believe it deserves publication. However, I have a few minor comments that I invite the authors to address.

The authors frequently reference PGA values in the introduction and throughout the manuscript. It would be beneficial to highlight the nature of this measurement. PGA is significantly influenced by site effects, such as soil type and conditions, saturation, and soil layer thickness, among others. These factors are not mentioned or examined in this study, despite their critical role in infrastructure design. Although there are brief mentions of these aspects (e.g., line 42 discusses near-fault PGA and line 45 mentions ‘when path and site effects are removed’), I recommend adding a clear statement that this manuscript exclusively considers 'near-fault PGA' and explicitly excludes site effects from its scope. This addition would, in my opinion, enhance the clarity of the study’s objectives in the introduction.

Figures:

Figure 1 d: the sketch of the complex rupture (in orange) is not completely clear. While the three thick lines show the overall rupture front temporal evolution for partial continuous and complex, the orange narrow curve at the top doesn’t add significant information. I suggest removing it or modifying it.

Figure 5: In my opinion, the current figure may not add significant new information to the discussion. While I understand that its objective is to highlight the knowledge gap between the fault state of stress and possible PGA measurements, I have some concerns: Panels a) and b) appear to repeat information already presented in Fig. 4a and c. Panel c) primarily shows an estimate of normal stress on a natural fault from Candela et al. 2011, which may not sufficiently enhance the overall argument. Given these points, I suggest that the figure might be omitted, and the reasoning behind it can be effectively incorporated into the text.

Typos/minor:

Line 67: repetition.

Line 98-99: The sentence is not clear to me. Is there a typo? Maybe the authors meant '… and on the low friction interface'?

Line 208-209: 'our ruptures are also'?

Caption Figure 2: panel c) I suggest mentioning/adding the name 'high-to-low spectral ratio ' as it appears in the text.

Caption Figure 4: 'peak slip rate marked by blue squares (or markers)'

Dear Editor,

I have reviewed the paper entitled “Heterogeneous high frequency seismic radiation from complex ruptures” by Cebry and McLaskey as a potential article to be published in Seismica. The paper report on laboratory experiments that have been designed to investigate the role of stress heterogeneity on the nucleation and propagation of a dynamic instability. The authors use PMMA as analog material for rocks and a technique that involves the artificial creation of a “bump” to induce stress concentrations in specific locations along the fault. The method of the technique are well explained in an almost companion paper previously published. In the present manuscript the authors analyze the source spectra of different types of unstable events that are controlled by the characteristics of the “bump”. The authors find that depending on the strength excess on the bump different types of rupture can arise from smooth to partial and finally complex. The authors find that complex rupture show a high frequency content when the bump undergoes dynamic rupture. They relate this complex behavior to the prominence of the bump that causes a strength excess as documented in the previous manuscript. They discuss their findings in light of the Peak Ground Acceleration (PGA) during dynamic slip instabilities and compare with natural faults that may show an analog behavior as observed in the lab.

The manuscript is very well written and logically organized. The figures are informative and complement the text very well. The topic is of broad interest in the geophysical community. I have very few comments as reported below that I hope will improve the manuscript. I believe that the manuscript can be published after minor revision.

I hope this help

Best

Marco Scuderi

Line-by-line comments:

L97-98: the author says that they load the fault at a constant stress rate but how this is transferred to the remote slip rate? By loading at constant stress rate can arise in heterogeneous slip rate at the boundary. Do the authors have a measure of the remote displacement rate? Furthermore at lines 103-104 they mention a run-in phase. How this stage is performed? Can the authors show in the supplementary a full experimental run?

L110: Here the authors state that all the signals were recorded under the same conditions but those conditions were not specified previously. Can the authors briefly specify the characteristics of the frequency band of the PZT and the instrument recording rate? Have the authors amplified the signal? Or eventually can the authors specify if these conditions correspond exactly to previous papers?

L152 and on the HLSR parameter: I find this parameter very interesting as a term of comparison between different styles of ruptures and stresses. However, I have a few questions in this regard:

– Can the authors motivate the choice of the high frequency band? From the spectra I see that the fall off is not very linear and a little noisy. Is only this the reason? The same is valid for the low frequency band, why the authors choose this band?

– Can the authors motivate what physically this parameter implies? I think it may be useful to add a few lines to explain what the variation of this parameter can imply in terms of the fault physical beghavior when coupled with source spectral characteristics.

L158: Here the authors very briefly mention that the remotely applied normal stress has an impact on the characteristics of the rupture. Since the authors have collected many data at different normal stress it would be very interesting to have a more thorough comparison between different normal stress. Is there some systematic difference in the radiation patterns? From figure S2 I can see that increasing normals stress and decreasing the ratio between the stress on the bump and the overall normal stress has an impact on the complexity of the rupture. This addition would also be useful for the final section of the application to natural faults since variation in nucleation depth may generate different PGA?

Figure 3: I found this figure very interesting but it can also be slightly improved in its clarity. Can the author slightly offset the displacement and acoustic signals? It would be nice if the authors can add marks on where they think the displacement curve start to show the onset of displacement. I have done it myself but it is not the best. I think this would help the reader in following the text.