Dear Dr. Tan,

We thank the reviewers for their constructive and thoughtful comments; we have revised the manuscript accordingly to address them item by item. We have also revised the figures to improve presentation and clarity. The revised manuscript, including all figures and source files, a mark-up copy, and a response-to-reviewers letter have been uploaded.

Please find below our detailed response to the comments of reviewer C and reviewer D. Line numbers refer to those in the revised manuscript.

Sincerely,

Harrison Burnett and Wenyuan Fan

----------------------------------------------------
Reviewer C:

This is a very well written and thorough paper, I have very few issues with it and think that it could likely be published as is. My major concern would be site effects affecting the analysis, however you addressed this with your ratio analysis and H/V analysis quite thoroughly.

Though if I were to make a suggestion for possible further analysis it would likely pertain to their analysis of the clusters swarm like behavior. Another method they might try is interevent time coefficient of variation. So the standard deviation of interevent time divided by the mean interevent time for a cluster or burst of cluster activity. Low coefficient of variations indicate more uniform interevent times that would be indicative of diffusive or aseismic drivers higher coefficient of variation would indicate the driver is more earthquake to earthquake interactions. See the paper below:
Cochran, E. S., Ross, Z. E., Harrington, R. M., Dougherty, S. L., & Rubinstein, J. L. (2018).Induced earthquake families reveal distinctive evolutionary patterns near disposal wells. Journal of Geophysical Research: Solid Earth, 123, 8045–8055.
https://doi.org/10.1029/2018JB016270

Thank you for the recommendation. We have computed the coefficient of variations, following Cochran et al., 2018, and have discussed the results. We find that the ten bursts analyzed in this study have a coefficient of variation between 1.26 and 3.16, which are similar to those observed in Cochran et al., 2018, suggesting these bursts cluster in time (see Line 181-188).

Another question I had was if the clusters seismicity you found in your analysis align with those found by Park et al. 2022. It seems like ok3 and ok1 do but ok4 and ok2 do not, which is interesting.

The reviewer is correct that the earthquake locations show variations between our study and Park et al., 2022.. These variations may result from different station coverages and the relocation procedures. In Park et al., 2022, the study applied a grid search association procedure and a three step location procedure including a double difference and waveform cross correlation relocation to a regional seismic network, while the Oklahoma wavefield experiment is much denser than the regional network with a nominal station spacing of 0.564 km.  We have now discussed these variations on Line 132-134.

The only other suggestions I have are fairly minor ones:

Figure 2: Background seismicity this is just unclustered seismicity from your own catalogs correct? Does circle size denote magnitude of the event? How do you deal with events that had no estimated magnitude?

Correct. The figure and figure caption have been revised to use  'unclustered seismicity' for clarification. Circle size denotes magnitude in the figure as part of the legend. For visualization purposes, events with no magnitude are plotted as M = -1.5 and this is now clarified in  all relevant figure captions.

For your magnitude estimation do you compare to other estimates of magnitude like from the Oklahoma catalog? This does not matter to much since your are not merging your catalog with others. I am just curious if you verified them.

We compared our magnitude with the Oklahoma Geological Survey (OGS) catalog (Walter et al., 2019). The M 2.3 event was the only event reported in this catalog in the region during the experiment. For this event, we compare our estimate with the OGS magnitude and use the difference to empirically correct all our magnitudes. Clarification has been added on Lines 111-113.

Lines 112-113: The events you could not estimate magnitudes for did you remove those from the catalogs and analysis or did you leave them in?

These events were not removed from the catalog. For plotting purposes, events with no magnitude were plotted as -1.5 M. As we focus on the spatiotemporal patterns of the earthquakes, we did not consider magnitude during the spatiotemporal analysis of the clusters. Regarding the wavefield analysis, these earthquakes all have assigned magnitudes, and we further quality control the analysis by applying a threshold for the signal to noise ratios of the waveforms. Clarifications have been added at Line 212.

Line 160: Episodic bursts of seismicity alternatively episodic bursts of seismic activity

Done .

Recommendation: Accept Submission

Reviewer D:
The manuscript presents detailed observational analysis of SH seismograms from a dense nodal seismic deployment in Oklahoma. It is an exploratory study of small magnitude clustered seismicity almost directly beneath the array at depths of only ~3-6 km. It has the simple guiding goal of analyzing wavefield similarity across the seismic array and among small events in the same cluster. The analysis appears technically sound, although I have one question below about a spatial averaging choice that may limit the scales of observable heterogeneity. Otherwise I have very minor comments that might help sharpen the text. Dense nodal and DAS arrays are becoming more common and I expect that detailed analysis of microearthquake source properties will be an increasingly active research area. This study introduces some useful simple approaches to scrutinizing such wavefields and draws interesting conclusions about the relative imprint of the focal mechanism and rupture process at different frequencies. I could see it aiding future research and stimulating healthy debates. I think it could be suitable for publication after minor revisions.

17. insert ‘that are’ before ‘located’

Done .

22. Can noise be ruled out?

We implement a strict signal-to-noise ratio threshold criteria to select wavefields for this analysis. The observed trend is unlikely due to noise levels.

23-24. Does earthquake slip also dominate at frequencies <12 Hz, or is something else dominant and if so, what? The non-technical summary seems to convey the message more clearly.

The reviewer is correct that slip also dominates seismic radiation at frequencies < 12 Hz. Here we highlight that slip also dominates at higher frequencies. We have revised the sentence to reflect the slip control on both low and high frequencies (Line 23-24).

183. perhaps ‘the best resolved’ rather than ‘most well-resolved’

Done .

198. should be ‘less than four’

Done.

200-201. The spatial moving average step should be accompanied by some explanation. Why do this before examining variability of the wavefields given that such smoothing will mute some of the recorded variability? How does this step change the spectra and does it limit the frequencies at which divergent behavior might be observed between stations?

The nodal stations are deployed at surface with varying degrees of coupling to the ground (Sweet et al., 2018). As this experiment was one of the first few to explore nodal array campaign experiments, a few deployment strategies were used, which can impact the observed wavefield amplitudes in this study. As the station spacing is around 100 m on average, spatial coherence between adjacent stations is expected due to the simple geological structure of the region. Therefore, the proposed smoothing strategy aims to reduce the impacts from noise and isolate patterns presented in the wavefield measurements. As the reviewer suggested, to examine the impacts of the smoothing windows, we have experimented with averaging the wavefields with a varying radius from 0.00135 to 0.0054 degrees (on average, this corresponds to 3 to 9 nodal stations being used in the moving average) (Line 212-220, Figures S1 and S2). We compute the interevent and intra-event correlations with these varying the radii of the moving average; we find that the differences in the results using different windows are minor, and that the relative patterns with frequency are about the same regardless of the size of the moving average. Given the findings, we opt to keep the radius of the moving average small (0.0027 degrees) to preserve some smaller scale features and suggest that different applications of similar approaches should evaluate this parameter to best address the associated scientific questions.

212-214. Based on visual inspection of Figure 6 I would not have reached this same conclusion that the overall pattern is similar. The location and azimuthal position of the maximum relative to the source changes quite a bit in some cases. For example, 6a predicted the maximum while it is observed in the northwest of the source for the higher frequency seismograms. The general decay with distance is similar for all the observational frequency ranges (b-e).

We have now added a comment noting there are some visual differences between the lower and higher frequency wavefields. We have also updated the figure to improve clarity. Please see Lines 230-232.

242. What else might they be caused by if not fault slip? It seems like an obvious conclusion but perhaps I'm missing something.

As proposed in Tsai and Hirth (2020), elastic impacts may control the high-frequency ground motion instead of earthquake slips. This idea is further explored in Trugman et al., (2021) who show that the observed wavefield becomes increasingly isotropic at higher frequencies. These findings suggest that the wavefields should become increasingly isotropic with frequency if our observed wavefields were controlled by the impact model. However, as we show in this study, the high frequency wavefields retain a structured spatial pattern, albeit with some heterogeneity. We have revised the sentence to improve clarity (Lines 260-261).

310. I'd encourage the authors to note the network code, time, and channel type here to facilitate other users accessing the data.  Recommendation: Revisions Required

Done.

-----------------------------------------------------

References:

Cochran, E. S., Ross, Z. E., Harrington, R. M., Dougherty, S. L., & Rubinstein, J. L. (2018). Induced Earthquake Families Reveal Distinctive Evolutionary Patterns Near Disposal Wells. *Journal of Geophysical Research: Solid Earth*, *123*(9), 8045–8055. https://doi.org/10.1029/2018JB016270

Park, Y., Beroza, G. C., & Ellsworth, W. L. (2022). Basement Fault Activation before Larger Earthquakes in Oklahoma and Kansas. *The Seismic Record*, *2*(3), 197–206. https://doi.org/10.1785/0320220020

Walter, J. I., Ogwari, P., Thiel, A., Ferrer, F., Woelfel, I., Chang, J. C., Darold, A. P., & Holland, A. A. (2019). The Oklahoma Geological Survey Statewide Seismic Network. *Seismological Research Letters*, *91*(2A), 611–621. https://doi.org/10.1785/0220190211

Sweet, J. R., Anderson, K. R., Bilek, S., Brudzinski, M., Chen, X., DeShon, H., Hayward, C., Karplus, M., Keranen, K., Langston, C., Lin, F., Beatrice Magnani, M., & Woodward, R. L. (2018). A Community Experiment to Record the Full Seismic Wavefield in Oklahoma. *Seismological Research Letters*, *89*(5), 1923–1930. https://doi.org/10.1785/0220180079

Tsai, V. C., & Hirth, G. (2020). Elastic Impact Consequences for High‐Frequency Earthquake Ground Motion. *Geophysical Research Letters*, *47*(5), e2019GL086302. https://doi.org/10.1029/2019GL086302

Trugman, D. T., Chu, S. X., & Tsai, V. C. (2021). Earthquake Source Complexity Controls the Frequency Dependence of Near-Source Radiation Patterns. *Geophysical Research Letters*, *48*(17), e2021GL095022. https://doi.org/10.1029/2021GL095022