Response Referee Comment 2 (RC2): Paper EGUSPHERE-2023-2570

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Dear Anonymous Referee #2,
Thank you for your time reading and commenting our manuscript "Proton Plasma Asymmetries between the Convective-Electric-Field Hemispheres of Venus' Dayside Magnetosheath" for publication in *Annales Geophysicae*. Your feedback provided valuable avenues to revise and improve our manuscript. Below we list your comments in italic text, followed by our responses in normal text.

In this work, the authors investigate plasma asymmetries in the Venusian magnetosheath. Using data from the Venus Express mission, they calculate mean values for proton density, velocity, temperature and magnetic field magnitude normalized to their solar wind counterparts. The authors take in hand a novel technique in order to calculate the plasma parameters, which later are organized according to the electric convective field. The main results do not show important asymmetries, but a secondary asymmetry on the velocity components leads to the second part of the paper where only the possible velocity asymmetries are studied. The final results are then compared with Mars and the comet 67P.

Q 1.1 *This reviewer finds a thoughtful analysis of the calculation of the moments, the choice of coordinate system, and the way the asymmetries are calculated for the observations. The authors claim that the clear asymmetries they found are for the proton density and the magnetic field strength with respect to the +E and -E hemispheres. This is not entirely true as the density shows very little asymmetry, while the magnetic field strength does not at all. So Conclusion 1 needs to be adjusted.*

Reply: We will revise Conclusion 1 to be quantitative (instead of just saying 'slight') and contrast with what previous studies observed.

Q 1.2 *What follows from there, is an effort to look for an asymmetry showing an important dependence on the convective electric field which is translated in a possible relationship between the Larmor radius and the velocity components. However, the comparison is forced after imposing several constrictions. The authors do mention that comparing with the Mars case is not possible and they move on to compare with simulations. These last show a partial match with the observational results from the manuscript. Then comes the comparison between Venus and the comet 67P is a major concern. As a direct comparison is not possible, the authors impose one assumption after another to their own results to be able to compare with the 67P. The physical meaning of such a comparison would lack veracity. In this sense, Conclusions 2 and 3 are dubious.*

The comparison with other non-magnetized bodies is not straightforward, even the authors are aware of it as expressed in the manuscript. I would suggest leaving out this section to a future work when a more direct comparison without too many assumptions could be done by the authors, which is -I believe- not the main point of this work and requires more work.

Reply: We greatly appreciate the feedback on the comparison with other non-magnetized bodies since this is the riskiest part of our analysis. It really is unfortunate that analogous studies at Mars or comets don't exist since they would provide valuable material for a great comparative-planetology discussion. Given the feedback, we plan to remove Section 4.3 entirely and rework Sections 4.1 and 4.2 into a shorter discussion which invites for further investigation of the topic instead of drawing such strong conclusions. Thus Conclusion 3 will be removed and the second part of Conclusion 2 will be revised. Figures 3 and 4 will be kept since they provide a useful exploratory analysis of Larmor-radius dependencies that a future study can delve into. Cutting out Section 4.3 will also open up space for expanding on methodology in Section 2 without making the paper longer.

Q 1.3 *The data spatial coverage is limited for high latitudes and yet the authors calculated the asymmetries for the range 0-90°. Wouldn't it be better to leave out the regions with poor coverage using some criteria from the beginning? Perhaps something related to the time the spacecraft was in that region or a threshold in the number of measurements required to consider those angles.*

Reply: We calculated the overall asymmetries excluding measurements at high latitudes (75° or more from central parallel) and the results don't change since there are much fewer scans there. Applying some criteria to exclude low-coverage regions is a good suggestion but not necessary for the analysis. We will mention in the manuscript that data from the low-coverage regions does not affect the final results or conclusions.

Q 1.4 *Limited IMA field of view issue: did the authors take into account only full 3D distributions to calculate the plasma moments or did they also consider distributions with partial angular coverage? In the second case, how do the authors deal with the lack of physical meaning for partial distributions?*

Reply: The plasma parameters were not calculated through moment integrals but rather through the VDF fitting procedure developed by Bader et al. (2019). This has the advantage of 'filling out' the VDF measurement whenever IMA did not measure the full distribution. This is only reasonable to an extent so the procedure includes quality metrics to filter out poor fits. We will include more details like this when we expand on methodology in Section 2.

Q 1.5 *(Line 65) In the documentation for the IMA-MAG database it reads "All solar wind (SW) parameters are medians calculated from IMA scans and MAG data not included in the file. These medians are assigned as the upstream SW conditions for each orbit (hence entries repeat for the same orbit)."*
The SW conditions change during each orbit, and the inbound leg of the orbit is unlikely to be preceded by the same SW conditions as the outbound leg. If one considers two data points, one closer to the shock in the inbound leg and the other closer to the shock in the outbound leg, it does not make sense to consider the same set of upstream SW conditions for both points (either upstream inbound or upstream outbound). One point should be associated with the closest SW region mapped by the spacecraft. So could you clarify which SW conditions are considered for an orbit: upstream inbound leg or upstream outbound leg? How do you choose which to use? If the exact same upstream SW conditions are taken no matter where the measurement point is, what is the effect of such a selection on the calculated asymmetries?

Reply: The magnetosheath measurements we consider are all located in the dayside. We thus use the solar-wind measurements upstream of the dayside bow-shock crossing for each orbit. These can be during the inbound or outbound leg, but always immediately before or after the magnetosheath scans. We will make this clearer when we expand on methodology in Section 2.

Q 1.6 *(Line 109) "The perpendicular and parallel temperatures exhibit the clearest symmetry between hemispheres (both overall and as a function of latitude)."*
In Figure 1, the asymmetries for Tpar and Tperp are clear; however, the parameter asymmetry in Figure 2 is visible for Tperp, but that is not true for Tparallel. Why is it so?

Reply: Judging asymmetry from Figure 1 is not appropriate since it corresponds to taking a ratio of medians instead of a median of ratios. The asymmetries shown in Figure 2 are the statistically superior way to calculate ratios since they are based on the entire distributions, not just a couple representative values like the quartiles. This advantage of the method is mentioned in Rojas Mata et al. (2023) and we will mention it again when we expand on methodology in Section 2.

Q 1.7 *(Line 134) If an artifact effect, shouldn't it be also shown in the third quartile and for all data.*

Reply: We are not exactly sure what is meant here. The third quartile for small Larmor-radii vx in the -E hemisphere is more to the left than the other two third quartiles which is what the small dip at -100 km/s would cause. The data for all Larmor radii do not show this dip likely because the other 75% of measurements don't feature it.

Q 1.8 *(Line 195) So the asymmetry for large Larmor radius is related to the fact that ions are picked-up more easily in that direction than in others? But, I would expect for this to happen far from the planet as* r_L *is large, therefore the asymmetry will be very hard to observe close to the planet.*

Reply: Simulations like those in Jarvinen et al. (2016) would provide a great opportunity to characterize the spatial extent of the asymmetry by calculating analogous latitudinal dependencies and maybe accompanying radial dependencies. Our results suggest that measurable differences in the solar-wind deflection occur close to the planet. Maybe this is due to the pick-up ions having much greater mass than the solar wind so even a little bit of transferred momentum noticeably deflects the solar wind. On the other hand, the relative densities also need to be considered since these also determine the total momentum of each species flow. A dedicated study analyzing data and simulations in the same way would provide important insight to these Larmor-radius trends.