Gabriella Stenberg Wieser 2026-07-09

UPDATES AND ANSWERS TO THE REVIEWERS' COMMENTS

We thank both reviewers for important and relevant comments, helping us to make the paper better. All major changes to the paper are made as a response to the reviewer comments and are described below. In additional we corrected the typos we could find.

REVIEWER 1:
This manuscript presents a useful in-flight calibration study of the JDC sensor onboard Juice, based on observations during the Earth flyby. The authors show that the original low-energy sweep table produced an unreliable energy assignment, especially at low energies, and that laboratory measurements of the ESA voltage can be used to reconstruct the effective energy scale. The corrected observations become more consistent with the spacecraft potential, and the new sweep tables will be important for future low-energy particle measurements near Jupiter's icy moons. Overall, the paper is interesting and timely. I recommend publication after revision. My main comments are listed below.

1. Spacecraft potential should be introduced earlier and connected to the target observations. The interpretation of low-energy ions strongly depends on the spacecraft potential, but the manuscript does not clearly explain why the spacecraft may charge negatively or positively in different plasma environments. I suggest adding a paragraph in the Introduction or Discussion to introduce this issue and link it to the relevant target regions, including Earth's plasmasphere during the flyby and the expected environments near Ganymede, Europa, and Callisto.

We extended the paragraph starting on line 34 (Introduction) as follows (Text inside [ ] is already exiting text):
[The Jovian Plasma Dynamics and Composition Analyzer (JDC; Wittmann, 2022), part to the Particle Environment Package (PEP; Barabash et al., 2026), is one of the sensors on Juice designed to observe the low energy ion populations at Jupiter's icy moons. Such observations are not trivial.] *Due to the interaction between the spacecraft and its environment a spacecraft gets electrically charged. Whether the spacecraft potential is negative or positive depends on the plasma environment, and is decided by a current balance (Garrett, 1981; Wipple, 1981). The main contributing currents are often the photoelectron current and the electron current. The photoelectron current is the result of solar photons causing emission of electrons from the spacecraft surface, driving the spacecraft positive. The electron current is the electrons in the plasma colliding with the spacecraft, driving it negative. As the plasma electrons are more mobile than the ions, the ion current is often negligible. In a dense plasma the electron current dominates over the photoelectron current charging the spacecraft negative. This happens for spacecraft in the Earth's plasmasphere (e.g., Kim et al., 2022; Zeroual et al., 2026) and Juice is expected to charge negatively in the ionospheres of Europa and Ganymede (Bochet et al., 2023). A charged spacecraft* [prevents low energy ions with the same charge from reaching the detectors. As an example, …]

2. The Introduction mentions previous Galileo and Juno observations of Ganymede's ionosphere, but the current knowledge of its low-energy ion population is still described rather briefly. Since the main result of the paper is the optimization of low-energy sweep tables, the authors should better explain what ion populations are expected at Ganymede, their likely energy range, possible ion species, and the main open questions. This would make the need for the new table more convincing.

As the paper focuses on the energy sweep tables and does not discuss the mass resolving capability of the JDC sensor, we would prefer to concentrate on this aspect of the future ion observations in the Jupiter system. We added the following text to the section "Optimizing future measurements", after describing the new energy sweep strategy, but before discussing the new energy tables:

The Juice mission provides a challenge for particle measurements, probing many different plasma environments. The six different sensors comprising PEP are designed to complement each other. JDC (together with JEI at the other side of the spacecraft) cover the mid-energy regime (~1 eV/q–35 keV/q) and must be able to detect heavy ions (e.g., O^+, S^{2+}, O^{2+}) in the Jupiter magnetosphere with energies up to tens of keV (Allegrini et al., 2022) as well as ionospheric plasma at Ganymede with energies below 10 eV (Frank et al., 1997; Valek et al., 2022). The observed energies of cold ionospheric ions depend on the ram velocity as well as the spacecraft potential. Heavier ions will be detected at higher energies than lighter ions. The Juno flyby of Ganymede in June 2021 suggests that an energy range of a few eV to a few hundred eV is a good choice for ionospheric observations (Valek et al., 2022).

3. The energy correction is central to the paper, and the current validation based on the removal of artificial banding and the consistency with spacecraft potential is convincing. I wonder whether it would be possible to provide an approximate uncertainty estimate for the corrected energies. This could include contributions from different sources, including but not limited to the laboratory voltage measurement, possible differences between the laboratory model and the flight unit, and the intrinsic ESA energy resolution. If a full estimate is not possible, a brief discussion of the dominant uncertainty sources would still be helpful.

We added the following text to section 5 in the paper:
The estimated uncertainty of the reconstructed energy levels shown in Figure 4 (red dashes) is about +/- 0.5 eV. Measurement uncertainties of U_{ESA} of about +/-50mV are the most dominant contribution to that. Also, for some energy steps, U_{ESA} was found to not have stabilized sufficiently within the 2 ms long settling time at the beginning of each energy step; these were removed from the data shown in Figure 5. The other main source of error are possible differences between the flight spare model of JDC on the spacecraft and the flight model available in the laboratory, estimated to add +/-40mV uncertainty to the value of U_{ESA}. The uncertainty of the JDC electrostatic analyzer constant E/U_{ESA} = 7.8+/-0.1 and the energy resolution of $\Delta E/E=0.15$ have both a negligible effect on the uncertainty of the corrected energies.

4. The choice of the three new energy ranges, 1 eV–35 keV, 1 eV–18 keV, and 1 eV–500 eV, should be briefly justified in terms of future science cases.

The new energy table with the maximum energy of 35 keV corresponds to the originally available energy table with the maximum energy coverage possible for JDC, but with corrected low energy settings. The justification for introducing a table focusing on low energies (1 eV–500 eV) is given in the answer to comment number 2, and the tables will be presented immediately after the (newly added) motivation in the manuscript. We believe this will make the choices clear.

The energy table with the maximum energy of 18 keV is an engineering compromise with reduced power consumption while still providing reasonable high energy coverage and improved low energy coverage. Such a table may be the opportunity to run JDC even when the power available is limited and hence increase the science return. This will be explained (basically with these words) when presenting the new tables.

REVIEWER 2:
The authors of "Flying through the plasmasphere to optimize low energy ion measurements" utilize the Juice spacecraft's flyby of Earth to improve the measurement scheme of the JDC instrument. Observations from the low-energy plasmasphere revealed that the voltage stepping of the instrument differed substantially from expectation. Performing laboratory experiments with the ground-copy of the instrument, the authors demonstrate that the observations can be correctly re-ordered to remove these stepping artifacts, which are further validated by a simple numerical model of the expected plasmasphere observations. Understanding the origins of the stepping issue, the authors present new voltage stepping patterns to maximize the scientific return of the JDC instrument during Juice's primary science mission at the Jovian moons. This work highlights the value of in-flight calibration to identify, understand, and

correct for instrument artifacts, and with the Juice spacecraft en route to the Jovian system, is timely. A few minor revisions are suggested.

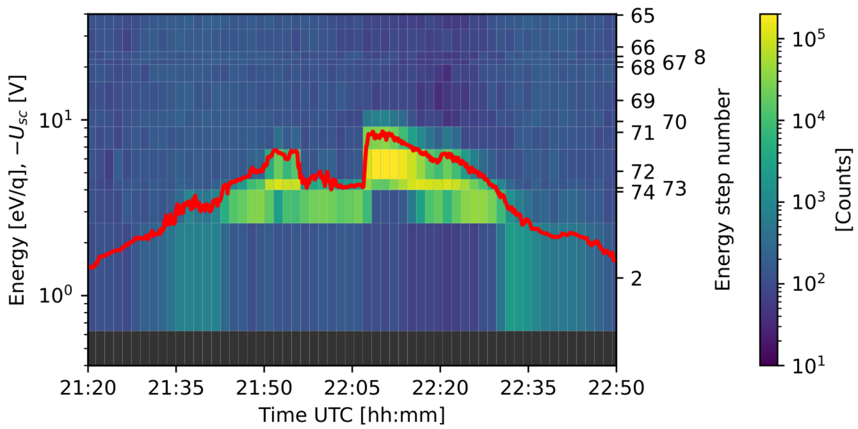
- In section 2, the authors are recommended to describe how JDC makes measurements of negative ion and electrons. Although the focus of the work is on the positive ions observed during the Earth flyby, the manuscript makes mention in several places about the negative-charged particle measurements, including how the voltage stepping will affect them too (e.g., lines 261-263). A sentence or two description early in the work would help readers that are less familiar with this type of instrumentation.

We added to section 2: By changing the polarity of the voltages applied to the electrostatic analyser and the deflection system electrodes, JDC can alternatively measure positively charged ions or negatively charged ions and electrons.

- Can the authors comment on the systematically low count rate below ~1 eV in Figure 5? The numerical simulation of the plasmasphere (Figure 7) suggests large fluxes may be present at these energies. Since the manuscript discusses the comparison between the re-ordered observations and the numerical simulation results, including the "holes" in the flux (line 225), it would be valuable for readers to understand if the low count rate in Figure 5 below ~1 eV is expected to be related to the actual plasmasphere (e.g., differences in ion species and temperatures) or an instrumental feature (e.g., related to geometric factor).

Firstly, Figure 5 contains a plotting mistake: bin 72 is plotted twice, the lowest energy bin should be shown as NaN values in the reconstructed spectrum (there was no energy bin below 1 eV, as shown in Figure 4). For visual impression, the colour bands fill the space between two energy bin centres, even if the energy difference between two bins is larger than the energy resolution. Below is the corrected Figure 5 including the correct unit counts, and not counts per second (cf. Technical correction below).

Secondly, the model we use is extremely simple. At energies below 1 eV it is not expected that the model will reproduce the measured data. Any protruding spacecraft structure like solar panels or any booms will result in near spacecraft ion trajectories that are significantly different from those obtained near a point-like spacecraft as in our model. Model fluxes may thus differ from the observed ones at these energies. We added a few sentences in section 7 to stress this in the paper: *At energies below 1--2\,\unit{eV}, the true shape of the spacecraft significantly affects the trajectories of particles reaching the detector. The point-like spacecraft used in our model cannot reproduce these effects and model results likely differ from observations.*



- A distinction between JDC's capability to resolve mass versus mass-per-charge would be beneficial to include in section 2. Traditionally, reflectron instruments are primarily capable of distinguishing species of different mass-per-charge. Does JDC enable resolution of mass and charge state? If so, that would be valuable to clarify since the plasmasphere can contain multiply charged species (e.g., line 104). If JDC only resolves mass-per-charge then it should be clarified if these plasmasphere observations are assumed to contain only singly charged species.

JDC does not enable resolution of mass and charge state. We added a clarifying text to section 2: *Species with same mass per charge, e.g., O^{+} and S^{++}, can only be statistically separated using the different energy loss at the time-of-flight start surface.*

- To aid in readers' mapping the different voltage stepping presented in Figures 3-5 it is recommended that the vertical range in Figure 4 is lowered. Comparing Figures 3 and 5, voltage step 73 exhibits a substantial re-ordering from ~0.1 eV in Figure 3 to ~4 eV in Figure 4. Since this step contains some of the highest count rates it would be valuable for readers to compare the expected vs. actual voltages in Figure 4, however, this is below the vertical axis of the plot.

The energy steps 72-74 in Figure 3 and 4 were nominally at 0 eV and could thus not be represented on the logarithmic scale. We harmonized the vertical axes on Figures 3-5 and added a note to the caption of Figures 3 and 4:

Figure 3:[…]*The corresponding tick-marks on the right-hand vertical axis correspond to the intended energy bin centre. For energy steps 72-74 the intended centre was 0 eV.*

Figure 4:[…] *The intended voltage setting for energy steps 72-74 is 0 V corresponding to 0 eV (not shown due to the logarithmic vertical scale).*

The updated Figures 3 and 4 are shown below.

Figure 3:

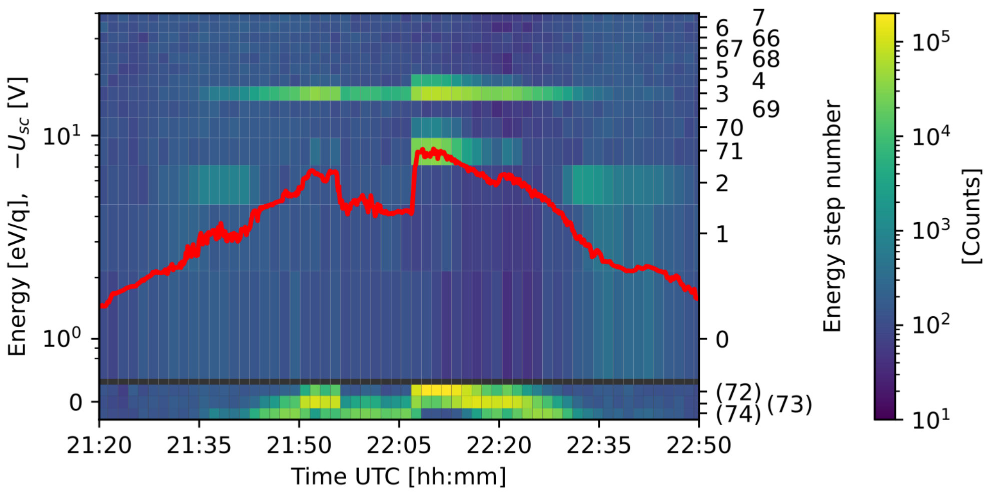
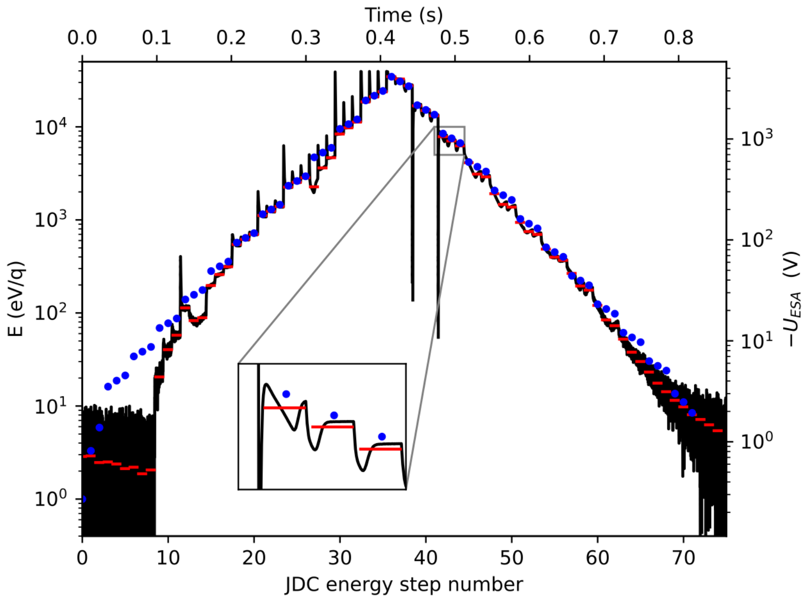


Figure 4:



Technical corrections:

- It should be clarified if Figures 3 and 5 show counts (as listed in the figure caption) or counts-per-second (as suggested by the "cps" label). Showing counts would be helpful to readers since it illustrates the instrument sensitivity (e.g., the 1-count limit) and uncertainty (e.g., Poisson).

The units in Figures 3 and 5 are counts. The figures were corrected in this regard (see updated figures above).