The manuscript presents the statute of the calibration pipeline for JANUS data as it is now, with nice demonstrations including examples of what physical effects and parameters are taken into account, what are the ones not yet taken into account, and what are the effects that have a yet undiscovered origin for further calibration. The paper do not focus on the theoretical calculations behind the calibration, but on the general principes and results of the calibration process. This is an important work for the analysis and interpretation of JANUS data.

I believe that the abstract could be more detailed, including the main findings about the state of the calibration pipeline. The figures are also often not described and explained enough in the text, nor the leaps from the figures to the conclusions to get from them. The paper would gain a lot by being more pedagogic in that sense. The readers of this papers that will work on already calibrated images of JANUS later on may not have all the theoretical knowledge necessary behind each step of the calibration process, so it is important to explain them in a pedagogic way. I understand that the detail of the calibration is to be written in another paper, but it was frustrating at time not to have the details of how many "models" were obtained, to better understand some of the figures.

Please find below my detailed comments:

ANSWER:

We thank both the Referees for their valuable comments and for having appreciated the work.

Comments by both Referees have been extremely helpful also in improving the internal consistency of the work, and make it more readable. All the images have been re-printed using color-blind friendly colors (colormaps for images: Batlow or Viridis. Discrete color palette: discretization of batlow or Okabe-Ito palette) or visually tested when not used. All the axis orientations have been checked and aligned to improve comparison.

We slightly expanded some sections (section 3.2) but we believe that a further expansion would be counter-productive. Our goal is to expose the logic behind the process to better support the data analysis and the other papers regarding the analysis of LEGA data. Our objective is to have a “supporting paper” rather than a “stand-alone” one.

We tried to go, for our understanding, in the direction of implementing the Referee suggestions or making our statements more clear, remaining in the spirit of this paper, as stated before. This has been made, specifically, carefully answering to the detailed comments.

In the next we address the specific questions:

Comments on main text:

- line 1: There may be a comma after Jovis in the sentence Jovis Amorum.....

  ANSWER:

  Fixed

- line 21-24: It's better to cut the sentence in 2

  ANSWER:

  Fixed

- line 88: genuine question : Why not lowering the threshold value described in line 85 then ?

  ANSWER:

  Because the two coefficients act on and describe two different logical sections of the pipeline. The first is the *actual* saturation level. We would like to have the real value, because it could be used in different analyses. The second coefficient "describes" our confidence on the calibration fitting procedure, because of the curve shape when the detector reaches the saturation. Fitting artifacts could rise. Currently we found this compromise.

- line 103: I believe a comma between the words "exposure time" and "generating" is necessary, depending on the meaning of your sentence.

  ANSWER:

  Fixed

- line 109: genuine question :Is there any physical reason why the dependence is assumed to be linear ?

  ANSWER:

  We did not identify a physical reason. Dark current usually has an exponential form with respect to temperature. We used the fact that the temperature range is limited with respect to the response of the detector to this effect and therefore we have considered it as just the first order term of a Taylor expansion. Our idea is, anyway, to explore better solutions. We have to collect more data to better understand and refine this model.

- line 111-113: Please explain each terms of the equation in the text (x0;w1;t0;t1,T...) event if it seems obvious. Also, add the units of the variables in the text if there is one (ex: [K] for T - or [°C])

  ANSWER:

  We modify the formulas in order to be more clear

$$DN_{bkg} = DN_{dark}(t_{exposure}, T_{detector}) + DN_{offset}(T_{detector})$$

$$DN_{bkg} = DC_{rate} \cdot t_{exposure} + B$$

$$DC_{rate} = (x_1 t_1 \cdot T_{detector} + x_1 t_0)$$

$$DN_{offset} = (x_0 t_1 \cdot T_{detector} + x_0 t_0)$$

  And in the text:

  "The contribution of the electronic background is the sum of the offset and dark current, where the first it is assumed to be dependent only from the detector temperature T_detector (°C), the latter from temperature and exposure time t_exposure (ms). The coefficients x1t1 (DN °C−1 ms−1) and x1t0 (DN ms−1) correspond to the slope and intercept of the linear model which is assumed to describe the evolution of the dark current rate DCrate (DN ms−1). The slope and intercept of the linear relationship assumed for the offset are instead x0t1 (DN °C−1) and x0t0 (DN). These four coefficients are all collected as maps of the same dimension of the image. "

- line 115: Figure 4 appears in the text before Figure 3. Therefore the figure numbers should be switched. Please, also precise how the average residual is calculated.

ANSWER:

Fixed. The sentence now is
Figure 3 shows the average residuals of the fitting procedure applied to the large dataset mentioned before. The average residual is computed by subtracting from each image of the dataset a synthetic image and generated using equation 1 and the estimated coefficients. The average is then calculated separately for each of the four tiles which form the detector, and are displayed with different colors.

- line 117-119: how do you see the contribution of the dark current ? Guide your reader in the interpretation of the figure and its results.

ANSWER:

We have explicited better the equations used for the fitting of the dark (see answer before), from which it should be easier to understand how it is possible to estimate the dark current contribution. Figures are not thought to derive the contribution of dark current but to provide the reader an insight into the quality of the fitting. Anyway we would like to provide to the reader the order of magnitude of the effect and the potential drawbacks.
The caption of figure 4 has been expanded
"Profile of a raw image along the column identified by index 0. orange: simulated background, due to offset and dark current. The simulated background is based on the fitted coefficients as described in section 3.4 and shows excellent results in subtracking the background from data, as also shown in figure 3c. The Pixel with higher dark current with respect to the average behavior (Hot pixels) are visible as spikes. The detector temperature is -36.8 C°, the exposure time is 113 s."

- lines 123-124: on line 123 you divide the proxy by the exposure time. On line 124 it is explained that the proxy is the radiance multiplyed by the exposure time. So in fine you are just using the radiance ? It was very confusing, and the need, use and meaning of a proxy value needs to be better explained

ANSWER:

We dived by exposure time not because we are *using* radiance, but because we *want* radiance.Using the proxy has two main reasons:
- it is easier to use in the same analysis data from different types of measurement (see ITFvs Radiance and ITF vs Texpo in section 5.1.8). This also improves the fitting because the number of points is higher.
- the main contribution to the non-linearity in the response is due to the accumulation of electrons, which in turn change the capacitance of the sensing node. In principle, therefore, the dependence is from a combination of the two parameters.

In this paper we would like to expose how the data are calibrated, to be in support of the data analyst, we will express the details in a dedicated paper.

- line 130: what are the spline parameters ? (how many consecutive data points taken into accounts ? is that what the 5 polynomial pieces means ?)

ANSWER:

"***We rephrased to be more explicit on how the curve is modelled:***

The response of each pixel is fitted using a least-squares spline (Figure 5), modeled as a B-spline with 12 knots (6 internals) and 8 coefficients. The polynomials composing the spline are cubic (order 4)."

Also we slightly modify the sentence

"The selection of the number of knots has been driven by the need" (number of pieces into number of knots"

- line 150-151: it is uncertain what is meant by "the latter" (the detector ? the band integrated radiance ?). In general I have trouble getting how it is necessary to correct from the target spectral shape, when it's part of the result

  ANSWER:

  We changed from "latter" to "signal itself". I think there is a little misunderstanding here. The correction is in general needed when the target spectral shape is different from that of the calibration source. This is because a radiometric calibration curve relates Digital Number (DN) to Radiance (or other proxies). This curve is the description to some extent of the product of spectral radiance and ITF (because it is the integral of this product that generates the photoelectrons in the pixel). Therefore it depends on which curve you are using. The calibration relates DN_calibration/radiance_calibration which in principle is different from the couple DN_target/Radiance_target. You have to convert DN values "as they were derived using a spectrum equal to the calibration source used". In this sense the spectrum of the target is "not part of the results", because using the calibration curve would require using the shape of the calibration lamp.

  A first step approach could be to perform the spectral calibration based on the solar spectrum, but in this way the spectral reflectance of the observed body is totally neglected. A proxy which is closer to reality is the use of an average spectral radiance of the body. As described in section 3.6.1 this information could be retrieved from MAJIS (imaging spectrometer).

- line 156-158: please add units of S, L, lambda when it applies.

  ANSWER:

  Fixed

- line 160: Table 3 cited in the text way before table 2. Please change table 2 number, as it is used last.

  ANSWER:

  The numeration is maintained since Table 2 should be cited by section 3.5. I added citation.

- line 162: Please write what LIME stands for.

  ANSWER:

  Fixed

- line 167-169: Please explains what is the I/F, and add the units of each terms in the text. In the equation, [AU] should not figure there, but in the text after *d*: d is the distance in Astronomical Units (AU).

ANSWER:

Fixed. Added the definition of the I/F according to Hapke, the units and the expression of C_filter is added as formula

- line 170: what does MODTRAN stands for ? can you tell more on this solar spectrum ?

  ANSWER:

  MODTRAN is a known software for solution of radiative transfer.
  We rephrased into:
  "The in-band solar irradiance is derived from the MODTRAN solar spectrum, to improve the cross-calibration with MAJIS, which already makes use of it in several analysis", to better highlight the spirit of collaboration with MAJIS colleagues that already makes use of the same spectrum, and to better highlight the reason behind the selection of that spectrum.

- line 173: you could write "and C_{filter}=pi.d/Int(E(lambda)dlambda)" of course using the proper mathematical symbols.

  ANSWER:

  Fixed

- line 174: Table 3 should become Table 2.

  ANSWER:

  Fixed, see answer before

- line 236: This is a high phase angle, could it create problems for some photometric corrections models ?

  ANSWER:

  Yes, photometric models suffer at high phase angles. Unfortunately this was a mission design constraint in which we had no control

- line 238: genuine question: Should the DTM resolution be adapted to the resolution of the image ?

  ANSWER:

  In principle, an ideal orthorectification would use a DTM with resolution equal to or finer than the image, so that each image pixel is associated with an independent elevation value. In our case this is not achievable: the SLDEM (Barker et al., 2016) is the only lunar DTM offering absolute geodetic accuracy with near-global coverage within ±60° latitude. Using a DTM coarser than the JANUS pixel scale does not invalidate the projection (it simply means the parallax correction is accurate at the DTM's spatial scale (60 m), not at the scale of individual JANUS pixels. In practice, the parallax effect arises because the line of sight from the spacecraft intersects the true, uneven lunar surface at a different position than it would intersect an idealized reference surface (e.g., a sphere or ellipsoid) at the same viewing geometry: the higher the local topography relative to the reference surface, and the more oblique the viewing angle, the larger this positional offset becomes. The effect is largest near the limb, due to the grazing viewing geometry imposed by the fixed 90° phase angle. A 60 m resolution DTM is adequate to resolve the broad-scale topography responsible for this effect, even though it is coarser than the JANUS image pixel. Higher-resolution alternatives do exist in principle (e.g., dedicated local DTM tiles or a DTM derived directly from the JANUS images themselves) but

these would require dedicated processing (tile generation, or stereo photogrammetry from suitable JANUS acquisitions) that falls outside the scope of the follow-up work that could be carried out after the LEGA execution.

- line 248: "all lines are captured simultaneously" the formulation is confusing if the meaning is something along "all pixels forming a line are captured/acquired" simultaneously.

  ANSWER:

  Fixed

- line 251: what is the "attitude" ? Please define it as you talk about it also latter in the text without explaining what that is.

  ANSWER:

  The sentence *"the position and attitude"* (first appearance of word "attitude") has been modified with *"the position and attitude (e.g. the spacecraft orientation with respect to another reference system)"*, for clarity

- line 294: Please describe and explain the figures in the text.

  ANSWER:

  Assuming you are taking about Figures 13,14,15,16 we expand the text with:

  "*We propose in this section three examples of measurements (Figures 13, 14 and 15): two of straylight contribution and one of ghost. The first example is displayed in Figure 13. Figure 13a shows a limb observation of the Moon in the outbound side of the lunar flyby. From this measurement four profiles are considered and displayed in Figure 13b. The visual representation of the acquisition geometry is shown in Figure 13c."*

  "The second example is shown in Figure 14, which has been acquired about 6 minutes after Figure 13. The instrument is observing the sky without any resolved target in the field of view but the baffle is still illuminated (out of field) by the Moon."

  "On 9 September 2024, while on its way to Venus following the Moon-Earth flyby, JUICE looked back to the Earth and the Moon from a distance of 5.7 and 5.3 million km, respectively. JANUS observed the Moon-Earth system for 10 minutes, tracking the Earth (Tubiana et al., 2026). The third example we present (Figure 15) comes from the observation of the Earth-Moon system."

  We think that this additional text complements the text already present and the reader will benefit from it. Please note that the Figure number is updated because of the suggestion to merge the figures in a single one

- line 298: please explain and define the terms in-field, near-field and out-of-field.

  ANSWER:

  We rephrased *"because in-field, near-field and out-of-field"* into *"because both in-field and out-of-field straylight contributions (that is signal coming from sources in and out of the*

field-of-view respectively) are present in these images." **I removed the "near-field" which is ambiguous although used in our Team**

- line 304: "previous case" -- It is unclear if you talk about figure 13 or 14.

  ANSWER:

  We were referring to Figure 13&14. I rephrase the section to:
  - make more clear the two cases (now called "examples")
  - make more clear that the Figure 14 is the geometry related to the example described by Figure 13

  detailed modifications:
  "We propose in this section three examples of measurements (Figures 12, 13 and 14): two of straylight contribution and one of ghost. The first example is displayed in Figure 12. Figure 12a shows a limb observation of the Moon in the out-bound side of the lunar flyby. From this measurement four profiles are considered and displayed in Figure 12b. The visual representation of the acquisition geometry is shown in Figure 12c."

  "The second example is shown in Figure 13, which has been acquired about 6 minutes after Figure 12. The instrument is observing the sky without any resolved target in the field of view but the baffle is still illuminated (out of field) by the Moon."

  Consider also the answer to next comment

- line 305: "same signal on the surface" -- I don't see the surface ? Or what do you means by it ?

  ANSWER:

  we rephrased the period, to be more explicit in the explanation. The surface is not visible because it is out-of-field,since it is the scope of the measurement. The reference signal is assumed to be the Moon as it was observed.
  Considering negligible variation of the illumination condition between the two images we can assume that the lunar surface generates about 7000 DN with 0.2215 ms (about 3.16 × 104 DN/ms) when it is in the field of view of the instrument. In the example of Figure 13, the Moon is out of field and produces a (straylight signal) of 3800 DN (the highest signal in the Figure) with 10000 ms. In this case, the lunar surface would yield 3.16×108 DN if positioned within the field of view, from which the straylight contribution is 0.0012%

- line 306: "0.0012%" - genuine question: is it really linear between acquisition time and DN ?

  ANSWER:

  The objective of this subsection is to provide an order of magnitude of the impact. The non-linearity of the radiometric response is not at the level of drastically modifying this result. A detailed analysis is on-going.

- line 314: please explain how do you see the 12000DN in fig 16, and how you obtains 0.0083%

ANSWER:

12000 DN is the saturation limit of the instrument. I rephrased the sentence to be more explicit on that and on the derivation of the 0.0083%

We expanded the section even with:

"On 9 September 2024, while on its way to Venus following the Moon-Earth flyby, JUICE looked back to the Earth and the Moon from a distance of 5.7 and 5.3 million km, respectively. JANUS observed the Moon-Earth system for 10 minutes, tracking the Earth (Tubiana et al., 2026). The third example we present (Figure 14) comes from the observation of the Earth-Moon system. In this situation the main source, the Earth, is over-saturated to raise the signal …"

… "During the same session, we acquired the Earth-Moon system with multiple exposure times using every filter JANUS has. The image acquired at 0.2215 ms (same source and same filter) results on both the Earth and Moon to be saturated. Since the saturation level for JANUS is about 12000 DN (see Figure 2), the rate is greater than or equal to 5.417 · 104 DN/ms. From Figure 14, the ghost pattern appears to have a signal less than 100 DN with 22.15 ms with an equivalent reference signal of 1.2·10^6 DN , that results in < 0.0083% of ghost signal contribution level"

- line 323: Describe and explain the figure in the text.

  ANSWER:

  we added
  "Figure 15a shows, for each filter, the histogram of the output of the absolute radiometric calibration module when an image with 0 DN is used. This corresponds to the calibrated version of an image with perfect removal of offset and dark current (and other effects such as straylight). Figure 15b shows the representation in the form of an image of panel (a) for the F1."

- line 345: please define QE.

  ANSWER:

  Fixed

- line 353: Table 2 here should have another number as it is its first appearance.

  ANSWER:

  See above

-

Comments on the figures:

In general, all captions need to be written in a way that the main text is not necessary to understand the figure. A lot of figures are missing labels on the y and x axis, and sometime on the colorbar. There is also a lack of consistency in the direction (toward the left or toward the right) of the x axis in the maps. Please ensure that all figures also are colorblind-friendly (especially the lines plots, and fig. 25). Figures treated in the same section could be regrouped in 1 main figure with subplots.

- Figure 1: The font sizes need to be increased, especially for 'par' and 'cal'. These terms should also be redefined in the caption.

  ANSWER:

  Fixed.
  Please note that the figure has been re-drawn to be more in line with figure 8. The caption has been modified in
  "Schematic of the radiometric pipeline implementation for the analysis of the LEGA data. Inside the circular box it is shown the type of operation applied, in order: identification (and filtering), subtraction, filtering, conversion and division. The product levels nominally generated by the pipeline are also shown : "raw" (data without elaboration),"par" (e.g. partially calibrated data, data without absolute radiometric calibration),"cal" (data with absolute radiometric calibration) . Please note that the last three steps are all part of the module which convert data in absolute radiometric units. Here the internal steps of the module are shown for clarity"

- Figure 2: missing y and x axis labels. The font size needs to be increased. Do you know why the tiles has such a difference in saturation ?

  ANSWER:

  Fixed. The difference is originated by the fact that the detector is structurally divided into 4 tiles, whose behaviour is different, having also different pre-amplifiers

- Figure 3: what are "hot" pixels ? Increase the font size of everything, but especially the legend. The fluo color for the green can be difficult to see on screen. The caption needs to be more detailed: simulated background of what ? simulated profile of what ?

  ANSWER:

  Assuming you are referring to Figure 4:
  Fixed (font size and colors)

  Caption rephrased into:
  blue: Profile of a raw image along the column identified by index 0. orange: simulated profile using the fitted coefficients as described in section 3.4. Pixel with higher dark current with respect to the average behavior (Hot pixels) are visible as spikes. The detector temperature is -36.8C°, the exposure time is 113 s. Orange represents the raw data and the green dotted line represents the simulated profile

- Figure 5: The figure is way too small, and so is the font.

  ANSWER:

  The figure is thought to be placed in a single column, so the size is limited. I increase the font

- Figure 6: add pixels lines and rows in axis labels. Please also recap what is included in the partial calibration.

  ANSWER:

  Fixed. The caption has been modified
  "Partially (a) and fully calibrated (b) version of the same image. Partially calibrated images

include the removal of offset and dark current and masking of invalid pixels. The vertical striping, introduced by the readout electronics, is removed after the absolute radiometric correction module."

- Figure 7: I have trouble understanding the full image. What are the white lines ? What is the module of distorsion vector ? And why is the unit in pixels ? when speaking about coordinates, is it a distorsion of the pixel coordinate (row, column) ? or probed space coordinates ? It really need to be better explained.

  ANSWER:

  We made an extra effort to clarify the meaning. In text:
  "T*he distortion maps are the final result of the analysis. JANUS distortion is represented empirically, as a pixel-offset lookup table, rather than through analytical polynomial coefficients. Figure 7(left) and Figure 7(right) show the x and y components, respectively, of this displacement field,together with isolines (in white) denoting the magnitude of the displacement, to better highlight the effect of the distortion. Each map takes the form of a JANUS full-frame image (2000×1504, line × sample), tabulated on the distorted-pixel grid. Each element stores the correction needed to recover the ideal (undistorted, pinhole-projected) coordinate from a given distorted pixel. The offset values vanish at the optical centre and grow to a few pixels at the detector corners, in a radial behaviour"*

  The caption has been rephrased

  "Distorted-to-ideal distortion map, shown as its x and y components (line and sample directions, respectively, as defined in the JUICE_JANUS reference frame in SPICE). Each matrix displays the offset between the ideal (undistorted) and distorted (actual) pixel coordinates, in pixel units, to highlight the effect of the distortion. White contours indicate the magnitude of the distortion vector, also in pixel units."

  We think that the use of JANUS pixel for unit is understandable from the context and appreciated by the reader, because it is easier to speak about pixel than millimiters on focal plane

- Figure 8: please increase the font of "der" and "geo". Define also DEM, and C-kernels.

  ANSWER:

  Fixed

- Figure 9: suggestion: the word "footprint" may fit better than "case". Remove the line crossing the round and cross data points in the legend

  ANSWER:

  Fixed

- Figure 10: please increase the font size

  ANSWER:

  Fixed

- Figure 11: please increase the font size, and add all axis and colorbar labels and units if it applies. for the right plot please check if the chosen color combination is colorblind-friendly. Check consistency of the direction of the x axis with other figures

  ANSWER:

  Fixed

- Figure 12: add axis labels and a colorbar. Check also the x axis direction. In the caption there is an inversion of blue and orange line. the blank spaces ? Please write it explicitly that the blank spaces are the saturated pixels

  ANSWER:

  Fixed

- Figure 13: Add axis labels, check x axis direction. join with figure 14. How do you know if the DN values before seeing the surface is due to straylight and not something else ?

  ANSWER:

  Fixed. Because currently it is the most plausible explanation, a straylight analysis is ongoing and preliminary it seems to be able to reproduce the pattern

- Figure 14: Place the x_sc (and same for y and z) in more convenient positions that do not hide lines or texts.

  ANSWER:

  Fixed

- Figure 15: Axis labels + x axis direction

  ANSWER:

  Fixed

- Figure 16: Axis labels + x axis direction. In the legend, the exposure time is 22.15 ms, which is not consistent with the text (0.2215 ms). Is there a target in the image ?

  ANSWER:

  Axes and direction are fixed.
  Probably the phrase was not clear enough. The image is correctly stated (22.15 ms). In the text we are referring to an image acquired in the same condition (some minutes before) but with 0.2215 ms, this one is already saturated and used as a terms of comparison.

  We rephrased, see comment above

- Figure 17: Increases font size. In the legend, the last 3 colors are the same as the first 3. Check if the image is colorblind-friendly

  ANSWER:

  Fixed

- Figure 18: Axis labels + x axis direction + font size

  ANSWER:

  Fixed

- Figure 19 & 20 : Uses the same scale in both DN axis. Labels missings in axis and colorbar. Also check for x axis direction consistensy with other figures

  ANSWER:

  Fixed

- Figure 21: increase font size, and add y axis label. The dotted lines could be larger

  ANSWER:

  Fixed

- Figure 22: all words in the legends need to be explained.

  ANSWER:

  Fixed.

- Figure 23: write CAD in full letters

  ANSWER:

  Fixed

- Figure 24: needs to be explained in details as I do not understand it.

  ANSWER:

  To improve the comprehension of the section the text has been rephrased:

  "Analysis on pointing requires the evaluation of different aspects of the system performance, as described in ESSB-HB-E-003 Working Group (2011). Figure 24 depicts (in red) the evolution in time of a generic quantity of interest (e.g. an angle of rotation of a reference system with respect to another one). Some performance parameters useful to characterize the system are:

  - ***Absolute Performance Error (APE) which is the difference between the target parameter (commanded) and the actual one.***
  - ***Absolute Knowledge Error (AKE) which is the difference between the current knowledge of the attitude and the actual one.***
  - ***Mean Performance Error (MPE) is the mean value of the APE in a selected time window. This window could be considered the observing window of JANUS during a science observation.***
  - ***Relative Performance Error (RPE) is the variation of the quantity under study during the observing window***

In this section we considered the effect of the AKE."
The caption of figure 24 has been rephrased

"Visual depiction of the evolution (in red) of a parameter under study (like a rotation angle) during the time. Some pointing errors are included (ESSB-HB-E-003 Working Group, 2011). Observing window is a generic JANUS scientific/calibration time period during which the instrument is observing a target. Acronyms: RPE (Relative Performance Error), AKE (Absolute PerformanceError), MPE (Mean Performance Error), RPE (Relative Performance Error)"

- Figure 25: Checks if the colormap is adapted to colorblindness, and for one of the black line, usedotted lines instead to differentiate them easily. What are the axis labels ?

  ANSWER:

  We changed the colormap to viridis, which is colorblind friendly and modify one black line in dotted. We added the axis too.

- Figure 26: Axis labels + font size

  ANSWER:

  Fixed

Comments on the tables:

- Table 3: Please recall what are S_moon and C_filter in the caption

  ANSWER:

  Fixed