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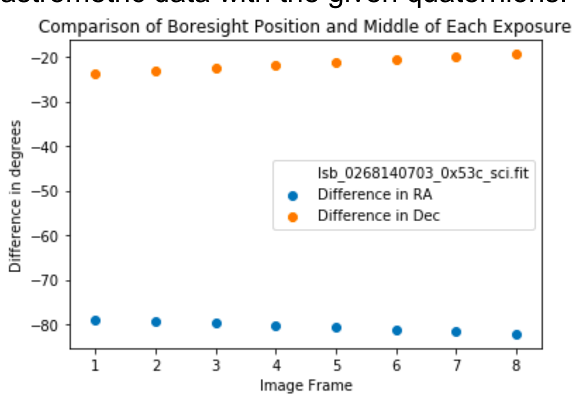
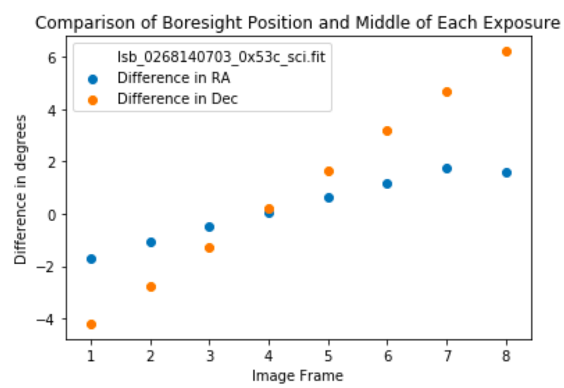
Dear SNB Administration Team,

I am working on archival LEISA data and would like to query an aspect of the publicly available data I believe to be in error. I am analyzing data from the Jupiter Flyby, Pluto Cruise, and Pluto Flyby phases of the New Horizons mission[1] and the Cruise to First KBO Encounter of the Kuiper Belt Extended Mission[2]. It appears that extension 7 of the FITS files in these datasets have incorrect or missing information. Extension 7 includes the ephemeris time and quaternion for each pixel in the image frame. In every FITS file I tried, the last value of this extension, which corresponds to the third imaginary component, or z-component, of the quaternion, is always equal to zero. This seems nonsensical when comparing to the quaternion given in the header as well as from tests I have conducted which I will present below. I would very much appreciate any insight you may be able to provide on this matter.

As an example, consider FITS image lsb_0397097519_0x53c_sci.fit from the “Cruise to First KBO Encounter” data. For this image, as for all images I have looked at, the z-components for each quaternion in the extension are always zero. However, the z-component for the instrument and spacecraft quaternion in the header (which I assume refer to the middle exposure of the FITS image) are 0.7321819521713311 and 0.7369291272291398 respectively. This discrepancy has not been explained by any reading I have done on LEISA, and according to my understanding of quaternions, must be in error.

To see whether or not this is actually a case of missing or incorrect data, I ran a series of tests. According to the *New Horizons SOC to Instrument Pipeline ICD* paper, each pixel has its own cartesian pointing vector and “by rotating the pointing vector of a pixel by the quaternion for the image frame, the J2000 pointing vector of each pixel can be derived”[3]. I attempted rotating the vectors two different ways: (1) using the quaternions from the extension for each frame; (2) using the scalar and first 2 imaginary components of each quaternion from the extension with the z-component of the instrument header’s quaternion. In each scenario, I compared the boresight coordinates that were given in the header with my computed J2000 right ascension and declination coordinates of the middle of each exposure. The plots below show the results of each approach, and each result in great differences. Considering the field of view of LEISA is 0.9°x0.9°, these differences are considerable and prevent me from calculating accurate astrometric data with the given quaternions.





Figures 1 and 2: Comparison of the boresight right ascension and declination coordinates given in the header of the FITS files with calculated coordinates of the middle of each exposure using approach (1) (left) and (2) (right). The differences are substantial, implying the zero component of the extension quaternion is incorrect and simply using the non-zero component from the header does not sufficiently make up for the discrepancies.

Figures 1 and 2 shown above are the results after applying approach (1) and (2) respectively. Approach (1) yields drastic differences between the expected coordinates of the boresight and what I calculated. This leads me to believe that the extension quaternions, with the zero z-component, are flawed. Approach (2) is a “band-aid” approach, which yields results that agree near the center frame, but get worse the further from the center exposure. I would expect this behavior if the third component of the quaternion information should be updated in each exposure; since the quaternion reported in the header is referenced to the middle integration, assuming that value should minimize the discrepancy. However, it is clear that information is missing, and the header value is not a complete description.

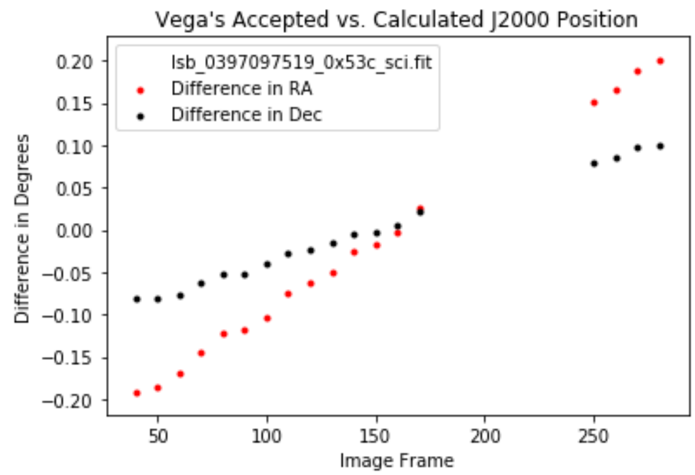


Figure 3: Comparisons of Vega’s position with the calculated position using approach (2). The differences in the accepted and calculated values are smallest in the middle frames and increase the farther away from the middle frames they are. This is expected as the quaternion from the header corresponds to the middle exposure of the image. Again, the fact that the positions agree well in the middle exposure shows that the zero component in the extension quaternions is incorrect.

Another test I conducted was to track the star Vega in the image labeled lsb_0397097519_0x53c_sci.fit from the “Cruise to First KBO Encounter” dataset. In this image, the star Vega is being scanned in a window as a slow scan test. For every ten frames, starting at frame 40, I recorded Vega’s position on the image, and recorded my calculated RA and Dec coordinates for each using approach (2). Figure 3 above shows the difference between the calculated position of Vega for each frame (the missing data points are due to Vega passing through a very noisy section of the image, making it difficult to see where it was). Again, the differences are smaller towards the middle frames and get larger farther from the middle frames. This is the same trend seen with the image boresight test.

I would like to request you review the latest LEISA data releases for both the New Horizons and the New Horizons Kuiper Belt Extended missions and check that you and the LEISA team believe the information in extension 7 is correct. I can be contacted by phone at 845-545-0408 or by email at djh5690@g.rit.edu. Many thanks for your regard of this matter.

Yours, Dennis Houlihan
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1. https://pds-smallbodies.astro.umd.edu/data_sb/missions/newhorizons/index.shtml
2. https://pds-smallbodies.astro.umd.edu/data_sb/missions/nh-kem/index.shtml
3. https://pds-rings.seti.org/newhorizons/SOC_INST_ICD.PDF