Comment on "An Active Plume Eruption on Europa During Galileo Flyby E26 as Indicated by Energetic Proton Depletions" by Huybrighs et al.

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Key Points

- The energetic proton flux decrease previously interpreted as the signature of a plume on the Galileo E26 flyby is an artifact
- There is yet no convincing evidence for a plume encounter on Galileo's E26 pass by Europa

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Abstract

The Galileo spacecraft passed close to Europa on eleven encounters, two of which (E12 and E26) came within 400 km of the surface. In E12 data, there are perturbations in field and plasma data consistent with effects of a nearby plume (Jia et al., 2018). Huybrighs et al. (2020 - https://doi.org/10.1029/2020GL087806) report depletions of proton flux in one channel of the Galileo Energetic Particle Detector (EPD) as Galileo passed close to Europa on E26. They trace particle trajectories in the magnetic field provided by a magnetohydrodynamic simulation and conclude that the spacecraft probably also passed through or close to a vapor plume on E26. However, the absence of a related signature in the measured magnetic field led us to question this conclusion. Examination of the EPD data remote from Europa on the E26 flyby reveals that the putative plume signature in the EPD data is an artifact.

Plain Language Summary

In recent years, there have been reports that plumes – or extraterrestrial geysers – rise hundreds of kilometers above the surfaces of Saturn's moon, Enceladus, and Jupiter's moon, Europa. A very recent paper examines data from a close pass by Europa (E26 flyby) made by the Galileo spacecraft on January 3, 2000. The paper identifies a localized decrease in the count rate of energetic protons lasting about 20 s very near closest approach to Europa's surface and attributes the decrease to an interaction with a plume rising above Europa's surface. In this "comment" we demonstrate that a localized decrease of proton count rates is recorded at the same point in almost each measurement cycle (every 280 seconds) even very far from Europa on this pass due to an anomaly in the Energetic Particle Detector (EPD) channel in question. Therefore, the use by the authors of the EPD data to establish the presence of a plume during this pass is erroneous. Our conclusion is that during E26 the Galileo EPD data has to date not shown evidence of a plume.

Main Text

Active plumes jetting water vapor above the icy surface of a moon were first identified in images of Neptune's moon Triton (Soderbloom et al., 1990). More than a decade later, disturbances in the magnetic field measured by the Cassini magnetometer just below Saturn's moon, Enceladus (Dougherty et al., 2006) were used to infer the presence of a vapor plume. Images soon confirmed that the plume was composed of multiple vapor jets (Porco et al., 2006) and the signature of water was identified by the mass spectrometer (Waite et al., 2006). Some time later, analysis of Hubble images suggested that water vapor plumes are, at least intermittently, present on Europa as well (Roth et al., 2014; Sparks et al., 2016, 2017). Subsequently, localized fluctuations of the magnetic field and the electron density measured on a very low altitude Galileo flyby of Europa (E12 with closest approach at 206 km) were found to correspond well to the changes that would be expected if the spacecraft had passed through a vapor plume with characteristics similar to those inferred from the Hubble images (Jia et al., 2018).

Only one of Galileo's Europa encounters other than E12 (E26 on January 3, 2000) came within 400 km of the surface. Arnold et al. (2019), building on the magnetohydrodynamic simulation of Blöcker et al. (2016), suggest that on this pass Galileo passed through a vapor plume between 17:59:30 and 18:01:00. Huybrighs et al. (2020) show that during this interval, there was a significant decrease of flux in the TP1 channel of the Energetic Particle Detector (EPD) that measures the flux of protons of energy 115-244 keV (Williams et al., 1992). Data from higher energy EPD proton channels are not presented in the paper.

Using the fields from magnetohydrodynamic (MHD) simulations both with and without plumes, Huybrighs et al. (2020) trace the trajectories of energetic protons and find that, for an assumed plume located at 60° Europa southern latitude and 140° Europa longitude with a scale height of 200 km, an opening angle of 15°, and a surface density of order 2.5×10^8 - 2.5×10^9 cm^{-3}, charge exchange with molecular oxygen produces a decrease of energetic proton flux similar to that seen in the data for a short interval just after closest approach to Europa.

In order to assess the validity of the assumption that charge exchange with a plume produced the decrease of flux in the lowest energy channel in the EPD TOF (time of flight) data, it is important to determine if the pattern of bite-out in the TOF fluxes in all three available energy channels are consistent with the assumption of loss through charge-exchange. Lagg et al. (2003), for example, carried out such an analysis using the EPD TOF data before concluding that there is a neutral torus along the orbit of Europa. The Huybrighs paper does not test the charge exchange process by analyzing the responses at different proton energies available (220-540 keV and 540-1250 keV), which in itself raises questions about the analysis and, consequently, casts doubt on the interpretation.

In the vicinity of the plume modeled in the MHD simulation the magnetic field (used to trace proton trajectories) rotates significantly (Huybrighs et al. [2020] Supporting Information – Figure S6). We have examined the Galileo magnetometer data looking for evidence of rotations in the vicinity of the putative plume. There is neither a rotation nor a flux pile-up of the sort that would be produced by interactions with the local increase of ion density in a plume, as can be seen in Figure 1.

The signature that Huybrighs et al. associate with a plume is a brief decrease of proton flux in the TP1 channel of the EPD instrument during the interval labeled *p* in Figure 2a (from Huybrighs et al. [2020] - Supporting Information). EPD data are available through the Planetary Data System (PDS). Figure 2b also shows the flux in the TP1 channel of the EPD detector over approximately the same interval using data obtained from PDS but on a different scale. We use a logarithmic scale that reveals strong decreases on each data cycle when the detector acquires data behind a foreground shield and measures penetrating flux. In Figure 2a the data taken behind the background shield are grayed out but the locations of the dropouts are visible and correspond to the drops in Figure 2b. The decrease of flux labeled *p* appears clearly in both plots. Huybrighs et al. suggest that the flux decrease within the dashed lines (labeled *p*) can be attributed to loss of protons through charge exchange with vapor in a nearby plume. In the next figure, we propose a different interpretation.

Figure 3 is a plot of TP1 data from 17:30 UT to 18:30 UT on the E26 pass. This interval starts and ends at distances roughly 13 R_E (R_E is Europa's radius, 1562 km) away from Europa and there are decreases in the proton count rate extremely similar to the decrease identified as a possible plume on almost every measurement cycle (spanning 280 seconds), as indicated by the purple arrows. The regular decrease to about 600 count/s even within the "p" region occurs only when the EPD telescope making the measurement is stepped to motor position seven. Although it is uncertain why an erroneous count level is sometimes returned when the telescope that supplies the TOF rates is stepped into this position, intermittent anomalies in measurements from motor position seven have been noted previously. In a study of the Europa plasma torus using data taken far from Europa, Kollmann et al. (2016) excluded data from sector seven "*because they often show anomalous behavior potentially associated with so-called cross talk with other sensors*." Other speculations regarding the cause of anomalies in the data from this sector have been advanced, but the source remains ambiguous and frequently the data taken in this motor position are consistent with data from nearby motor positions. The sporadic nature of the error may explain why it was not noticed by the EPD team during the active mission.

In conclusion, we believe that the energetic proton flux decrease interpreted as the signature of a plume on the Galileo E26 flyby by Huybrighs et al. (2020) is an artifact associated with data acquired in a particular look-direction of the EPD detector and conclude that there is yet no convincing evidence for a plume encounter on Galileo's E26 pass by Europa.

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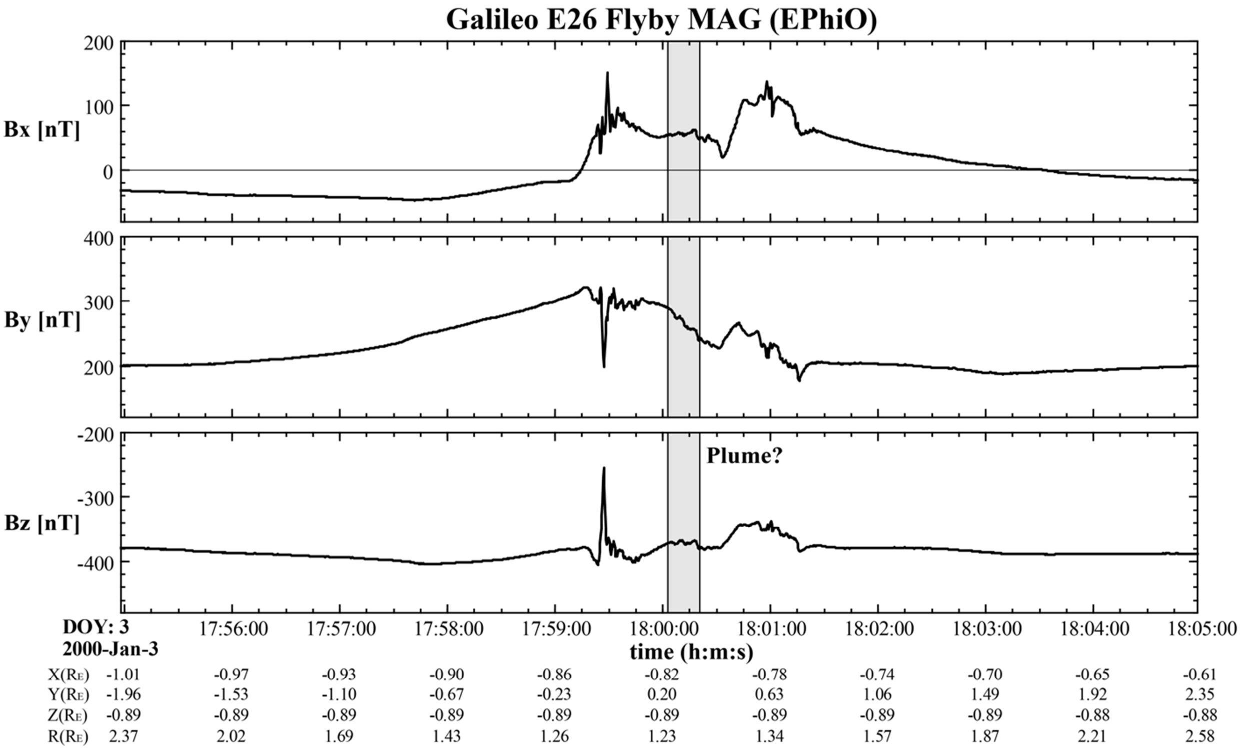

Figure 1. Three components of the magnetic field measured on Galileo's E26 pass by Europa on January 3, 2000. The interval identified by Huybrighs et al. (2020) as passage through or near a plume is shaded grey. There is no local feature evident in any component of the measured field.

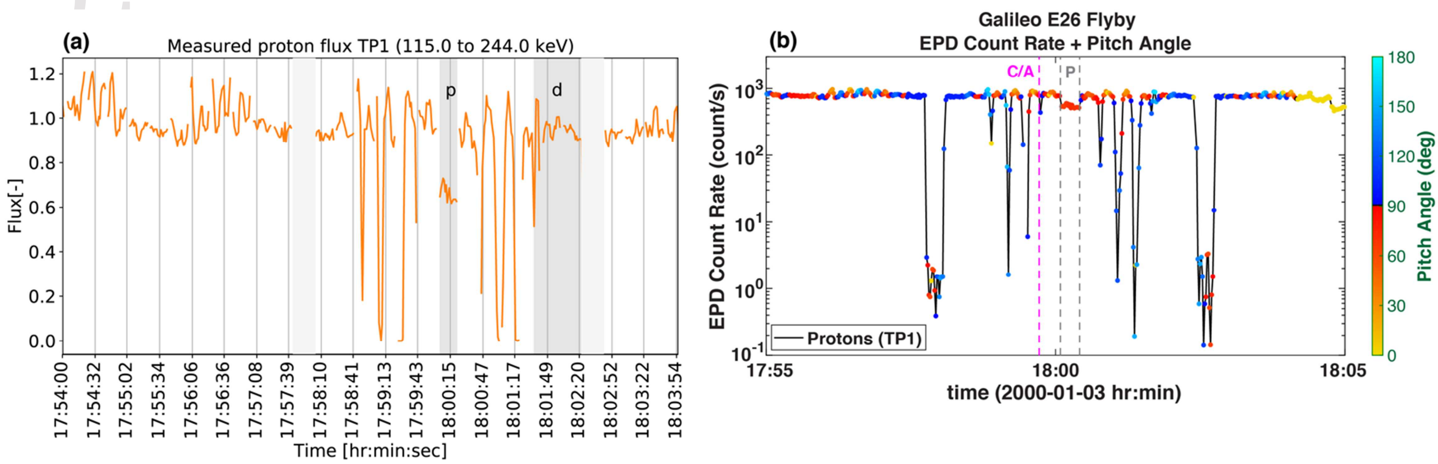

Figure 2. Flux (counts per s) of protons of energy 115-244 keV (the TP1 channel of the EPD) vs UT on Jan. 3, 2000 near closest approach to Europa on Galileo's E26 pass. (a) A portion of Figure S4 from the Supporting Information of Huybrighs et al. (2020) plotted on a linear scale. (b) Data from the same channel obtained from PDS archives and plotted on a logarithmic scale with colors indicating pitch angle as provided in the PDS data.

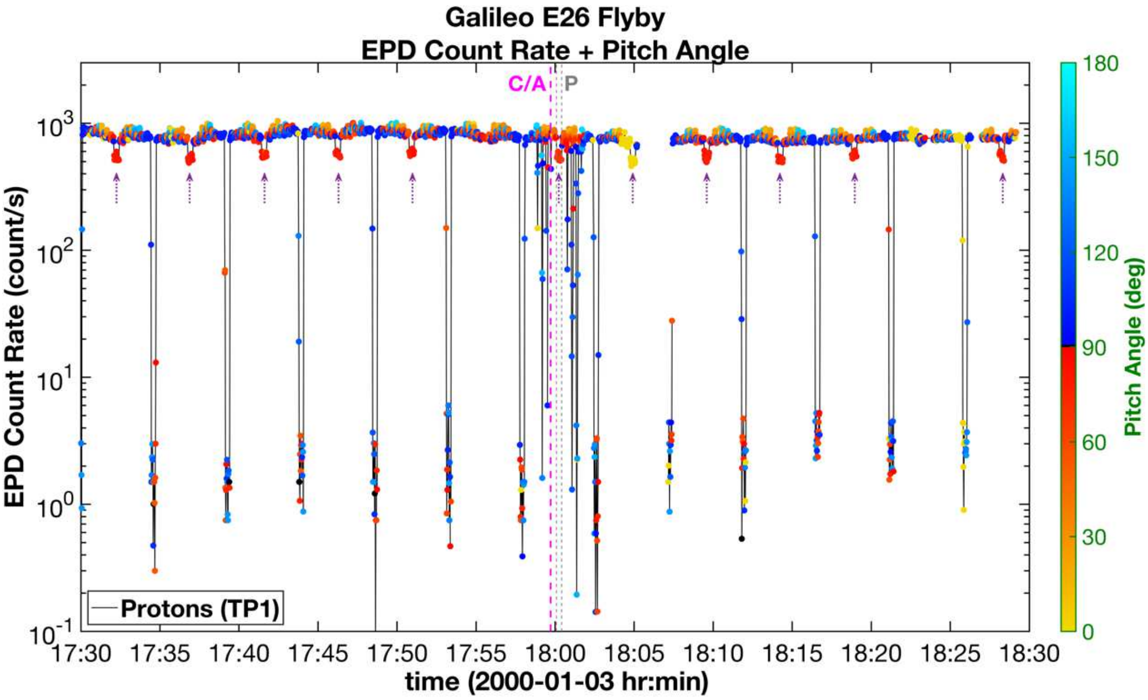

Figure 3. As for Figure 2b, but for one hour on Jan. 3, 2000 around closest approach to Europa on Galileo's E26 pass. As indicated by the purple arrows, flux decreases occur half way between successive measurements behind the foreground shield on almost every cycle, even those at a significant distance from Europa.