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Plasma Environment near Europa based on Re-analysis of the Voyager and Galileo Plasma Science Experiment Data

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Abstract

Re-analysis of the Plasma Science experiments (PLS) on the Voyagers (~10 eV to ~5 keV) and Galileo (~1 keV to ~50 keV) have refined our understanding of the plasma environment at and near the Jovian moon Europa. The warm plasma environment (i.e., ~1-50 keV) measured by the Galileo PLS has previously been at best poorly defined as the PLS electron data were found to have been contaminated by high energy electrons. To address this issue, the raw PLS data have been re-analysed orbit by orbit and detector by detector. The results indicate that the Voyager and Galileo spectra, previously fit by Maxwell-Boltzmann distributions, may be better fit by a more complex combination of a Maxwell-Boltzmann distribution plus a Kappa distribution or a polynomial fit in energy. The new spectra derived from the Voyager and Galileo PLS instruments between 8 Rj and 10 Rj are presented in this paper. This new model has important implications for instrument design and can also serve as a means to better understand and constrain the magnetospheric environment around Europa.

1. Introduction

The most current version of the Jovian radiation environment model at JPL is defined in three distinct energy regions: low energy plasma (< 1 keV), warm plasma (1 keV < E < 100 keV), and high-energy radiation (> 100 keV). While the low energy plasma and high energy radiation environment models are based on actual in-situ data from Galileo and Voyager, the warm plasma model is only defined through a kappa distribution fit (especially between 8-10 Rj) by smoothly connecting the low energy plasma region to the high energy radiation region. The Galileo PLS data for the warm plasma are available in this spatial region, but were not used in the model development because JPL found the data to be saturated inside ~14 Rj and thus less reliable based on a preliminary analysis (see next section). The objective of this paper is to provide an update on the status of the development of the JPL electron plasma models between ~1 keV to 50 keV [1] from re-analysis of the Voyager and Galileo PLS data between 8 – 10 Rj.

2. Data Sources and Analysis

The main data source for the plasma environment modeling in the spatial range between 8-10 Rj has been the two Voyager PLS experiments for < 5 keV. Details of the original Voyager PLS data analysis are presented in a paper by Sittler and Strobel [8] in terms of total moment densities and temperatures. Recently, Dougherty has revisited the Voyager PLS data base and has provided new estimates of the Maxwell-Boltzmann temperatures and densities between ~10 eV and 5 keV and the detailed differential number fluxes over this energy range (Private Communications, 2018). Note that the Voyager PLS does not provide the data for > 5 keV, while the Galileo PLS data are available between ~1 keV and ~50 keV, thus covering the warm plasma energy range. However, as indicated above, the Galileo PLS data have not been used extensively (at least for the spatial region between 8-10 Rj) because a synoptic analysis using the data averaged over the "mission" showed them to be contaminated by high energy electrons. This is evident in Figure 1. To resolve this apparent saturation issue and to extract useful data from the Galileo PLS, a different analysis approach has been suggested. We have carried out an analysis of the "orbit-to-orbit" variations in the Galileo PLS electron data using the E2, E4, and E6 PLS sensors and at a higher energy resolution than that provided by the E4 synoptic mission data base. Sample results for 3 orbits between 8-10 Rj and for the detector E4 are shown in Fig. 2. This figure highlights the details visible in the higher energy resolution data and the variability of "noise" below ~3 keV in sensor E4. Estimates were made of the background noise level variations between ~10 to 100 eV and then extended up and down in energy as illustrated by the red line for each orbit. This "background" was subtracted from the count rate spectrum for each orbit. More details on the background contribution will be described in the final paper.

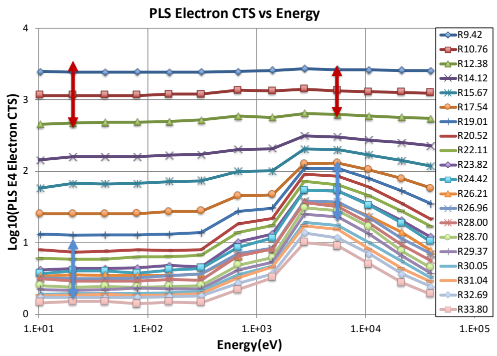

Figure 1: Plot of the PLS E4 electron spin-averaged count rates averaged over L intervals of 1.5 L versus energy (the average Rj for each interval is listed on the right side). Representative error bars assuming a log-normal distribution are indicated by the vertical bars.

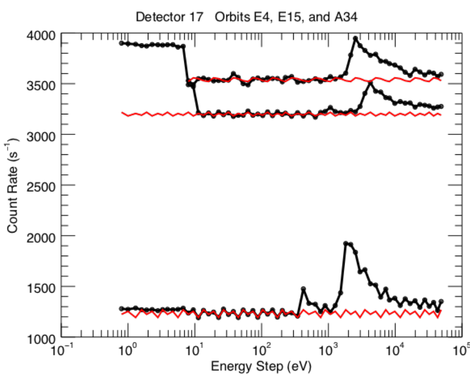

Figure 2. Raw counts for PLS detector channel E4 at high (64) resolution energy steps for orbits E2 (bottom), E25 (top), and A34 (middle) between 8 and 10 Rj for comparison with the mission-averaged values in Fig. 1. The red lines are fitted estimates to the oscillating background noise levels between ~10 eV to 200 eV extended up and down in energy.

3. Summary

The results, corrected for high energy resolution background, channel width, geometric factor, and efficiency are used to develop the plasma spectrum model as a function of Rj. An example of a detailed spectrum in energy as estimated in this study is plotted in Fig. 3 at 9.49 Rj. The hashed (i.e., with error bars) data are detailed spectra from this study based on the Voyager and Galileo PLS instruments and the Galileo Energetic Particle Detector (EPD). The differences between the original JPL Kappa fit and this study's more detailed estimate approaches factors of ~5-10 between 3-30 keV. An additional issue is the divergence between the JPL cold component (DFE1 in Fig. 3) and the detailed Voyager spectrum below 1 keV. The reason for these differences is due in part to the differences in the fitting techniques, namely Maxwell-Boltzmann and Kappa spectral fits for GIRE versus the actual differential energy spectra. The final paper will include the complete and more detailed description of all steps taken to develop the new plasma model in addition to recommendations for future studies.

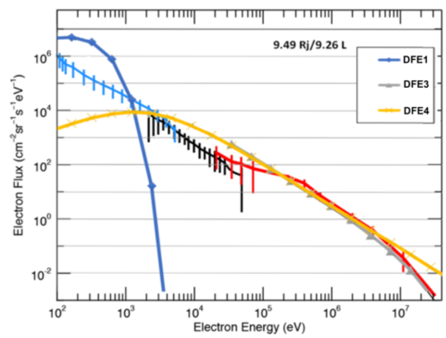

Figure 3. Differential electron fluxes at Europa (9.49 Rj). The blue line (hashed) is the Voyager PLS differential flux with error bars, the heavy black line (hashed) is the Galileo PLS differential flux, and the red line (hashed) is the Galileo EPD differential fluxes. DFE1 (blue/diamonds) is the cold electron component, DFE3 (gray) is the EPD model flux, and DFE4 is the Kappa fit given by the JPL original models.

Acknowledgements

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