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Energetic Electrons in the Jovian Magnetosphere Detected by the Alice UV Spectrograph Aboard New Horizons

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Abstract

In addition to SWAP and PEPSSI, the two instruments dedicated to measuring in situ particle fluxes, the New Horizons spacecraft is equipped with a third instrument that is sensitive to high energy electrons: the Alice UV spectrograph. Electrons with energy > 470 keV can penetrate the thin aluminum housing of Alice and interact with the microchannel plate detector, producing a count that is indistinguishable from a photon event. When both instruments are operating, the count rates of Alice and the Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI) electron sensors are highly correlated, confirming that the Alice count rate serves as a direct measure of the energetic electron flux at New Horizons, especially during times when the Alice aperture door was closed and no FUV photons could reach the detector. Over a 10-day period beginning on 22 February 2007, Alice recorded the integrated detector count rate with a duty cycle of 44%. Since the Alice count rate was sampled once per second, this data has the highest time resolution of any data set of energetic electron fluxes at Jupiter, although it is lacking any spatial or energy resolution. Alice observed an upstream solar wind event while 110 R_J from Jupiter. One and a half days later, Alice observed the magnetopause crossing at a distance of 67 R_J, suggesting the Jovian magnetosphere was in a compressed state during the New Horizons encounter. During the inbound leg of Jupiter flyby, Alice observed the energetic electron flux to be intense and highly variable. After closest approach, data from Alice and PEPSSI show spikes in count rate every five hours, the signature of the Jovian current sheet crossing over the spacecraft. During periods when New Horizons was out of the current sheet, the Alice count rate dropped to within a factor of two of the pre-Jupiter background levels, suggesting that the energetic electrons on these flux tubes have been lost.

1 Introduction

The Alice ultraviolet imaging spectrograph on New Horizons is a low-mass (4.4 kg) low-power (4.4 W) instrument [1]. Alice covers a wavelength range of 520–1870 Å with a spectral resolution of 3–4.5 Å FWHM and has a field of view 6° long. However, the microchannel plate detector is also quite sensitive to energetic electrons: lab tests showed a 33% detection efficiency for 1 MeV electrons. Electrons with energies greater than 470 keV can penetrate the 0.76 mm thick aluminum instrument housing and interact with the detector, producing counts indistinguishable from those produced by UV photons.

2 Results

For a 10-day period beginning on 22 February 2007, during which New Horizons went from 134 R_J upstream of Jupiter through closest approach on the dusk side of Jupiter at a distance of 32 R_J to 115 R_J downstream of Jupiter, Alice was on and at its operational voltage level. While on, the total count rate of the Alice detector is recorded in housekeeping data, and at Jupiter, it was sampled at a rate of once per second, giving Alice a higher time resolution than any other "electron detector" yet flown to Jupiter. We divide the Jupiter flyby into three segments: upstream, the inbound magnetosphere leg, and the outbound magnetosphere leg.

When the Alice aperture door is closed, the total count rate is highly correlated with the electron fluxes observed by the PEPSSI instrument, with a Pearson linear correlation coefficient of 0.94 for the 190-700 keV energy bin. When the aperture door is open (intermittently), the additional count rate from FUV photons can usually be removed by assuming it varies linearly during the observation.

2.1 Upstream Conditions

On 7 January 2007, when New Horizons was 1160 R_J upstream of Jupiter, the Alice count rate was 99 counts s^{-1} and constant with time. On 22 February 2007, at a distance of 134 R_J, the count rate had risen by 15% to 114 counts s^{-1}, likely due to energetic electrons escaping Jupiter. The Alice count rate continued to increase as New Horizons approached Jupiter.

The Michigan Solar Wind propagation model [3] predicts that a large solar wind compression event reached Jupiter on 22 Feb. Both PEPSSI and Alice show a strong increase (a factor of 3 for PEPSSI) in the energetic electron flux at New Horizons on this day.

2.2 Inbound Magnetosphere

At 17:50 UTC on 25 Feb., when New Horizons was at a distance of 67.5 R_J from Jupiter, the Alice count rate increased from the upstream background level of 150 counts s^{-1} to 6500 counts s^{-1} in 80 minutes. This sudden increase in count rate, is due to the increase in the energetic electron flux as New Horizons crossed the Jovian magnetopause. The location of the magnetopause suggests that the Jovian magnetosphere was in a compressed state during the New Horizons flyby [2].

From the magnetopause crossing through closest approach, the energetic electron flux at New Horizons was intense and highly variable, on timescales of both minutes and hours. During this period, Alice observed numerous $\sim$2x changes in energetic electron flux on timescales of 100 s. The count rate was often high enough to cause Alice to shut down and enter a safe mode. During a two-hour period centered on closest approach, the Alice data show a 25-minute episode of quasi-periodic bursts with periods of roughly 200 s. The next 40 minutes of data show no such rapid, quasi-periodic variations.

2.3 Outbound Magnetosphere

After closest approach on the dusk side of the magnetosphere, the energetic electron flux was less intense, and the Alice count rate showed clear peaks when New Horizons was near System III (1965) longitudes of λ_{III}=130° and λ_{III}=280°. We interpret these peaks in count rate as the Jovian current sheet sweeping over the spacecraft twice per Jovian rotation. In total, Alice observed 9 current sheet crossings; five additional current sheet crossings were identified from PEPSSI data taken during periods when Alice was not operating.

Between current sheet crossings, the Alice count rate drops sharply. In the most extreme case, there is a factor of 30 difference between the count rate during the current sheet crossing and immediately afterwards. Beyond roughly 60 R_J downstream of jupiter, the count rate outside the current sheet is less than a factor of two above the pre-Jupiter count rate observed on 7 January 2007–the plasma in these flux tubes appears to have been lost.

For reference, we have compared the location of the observed current sheet crossings to that predicted by the model of Khurana and Schwarzl [4]. A constant shift of 8.2º in longitude is required for the model to best match the Alice data. In addition, the Alice data support a hinged current sheet, with a hinge distance surprisingly close to Jupiter (-20 R_J), in contrast to the best-fit value during the Galileo epoch of -47 R_J.

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