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Using the McIlwain L-Value to Model Energetic Electrons at Jupiter

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Abstract

This report has two related goals: to establish the region inside Jupiter's magnetosphere where the McIlwain *L* value is a useful parameter for organizing energetic electron data and to is see if there are any clear reasons to prefer one of the two magnetic field models developed by Connerney [1] and Khurana [4] (referred to as 'VIP4' and 'Khurana'). We find that the McIlwain *L* value is useful for organizing energetic electrons inside of 15 *L*. In some instances, this region can be extended, but not as a general rule. The VIP4 and Khurana models use the same internal magnetic field source terms and consequently estimate the same *B* and *L* values (within 5%) inside of 15 R_J along the inertial equator. Consequently, there is no clear advantage of using VIP4 or Khurana for organizing energetic electron inside of 15 *L*.

1. Introduction

The McIlwain *L*-parameter was developed to help organize large gradients in energetic charged particle intensities within a dipole-like magnetic field [3]. Therefore, it is expected to be useful mainly in the inner region of Jupiter's magnetosphere, where the internal component of the total field dominates. Here, two different Jupiter magnetic field models are compared: the Voyager, Io footprint, and Pioneer fourth order model (VIP4) [1] and the 'Khurana' model [2] (specifically, the version used here is KT_2003_sub.f, provided by *K. Khurana* in 2009). The primary goals of this analysis are to identify the region within Jupiter's magnetosphere where the McIlwain *L*-value is a useful parameter for organizing energetic particles and to see if there is a clear preference for either the VIP4 or Khurana models.

2. McIlwain L-Value

The McIlwain *L*-value and the magnetic field strength can be used to effectively organize energetic electron populations in dipole-like magnetic fields. The combined bounce and drift motion of a particle's guiding center trace out a shell, called an *L*-shell, which refers to the McIlwain *L*-parameter [3]. In a dipole-like field, the relationship connecting *L*, the mirror magnetic field strength, B_M and a form of the second adiabatic invariant, *I,* defined by McIlwain is given by:

$$\frac{L^3 R^3 B_M}{k_0} = F\left(\frac{I^3 B_M}{k_0}\right). \tag{1}$$

On the right hand side, *F* is a function of the invariant, *I*, the magnetic mirror location field strength, B_M, and the planetary dipole moment, k_0.

3. Jupiter Magnetic Field Models

The most recent references for the VIP4 and Khurana models can be found in [1] and [4], respectively. (The version of Khurana used in this analysis, KT_2003_sub.f, has been updated.) Both include a strong internal dipole moment that dominates the inner magnetosphere structure. Additionally, each model includes external fields that warp the dipole. Despite differences in the external components, each model contains identical internal components. Therefore, the differences in the two models are solely in the external components. Figure 1 shows calculated *L* along the equator at 180° W (SIII) using both the VIP4 (blue) and Khurana (red) models. Additional figures that will be presented in the full workshop will support the assertion that along the intertial equator inside of 15 R_J, the two models predict similar total magnetic field strength and McIlwain *L*-values (to within 5%), regardless of longitude.

4. Using L to Organize Energetic Electron Observations

Figure 2 shows >11 MeV electron count rate from the Galileo EPD instrument as a function of *L* calculated using the VIP4 model (blue) and the

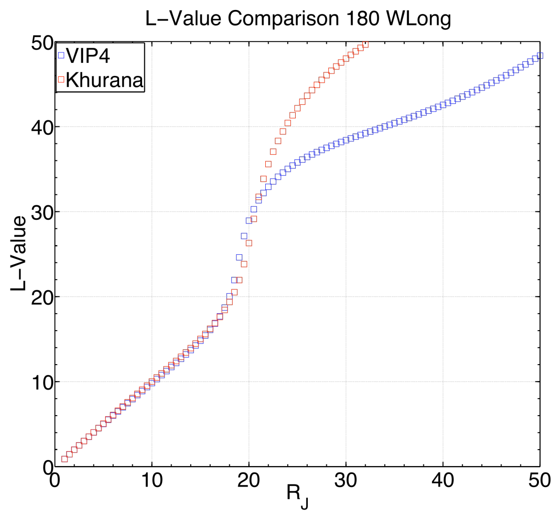

Figure 1: Calculated L values along the inertial SIII equator and 180° W longitude. L was calculated using eq. 1 and the VIP4 model (blue) and Khurana model (red).

Khurana model (red) during Galileo orbit C09 inbound. If the >11 MeV electron intensity at Galileo is isotropic, then the observed average count rate will be constant along a given L (or within a single fluxtube). Inside of 17 L, there are relatively smooth variations in count rate with little spread. Outside of 17 L, the count rate is not directly correlated with L, suggesting that the McIlwain L parameter is not useful outside of L = 17 for this orbit. This is true regardless of which magnetic field model is used. Additional figures that will be presented in the full workshop will support the assertion that the McIlwain L-parameter is useful for organizing energetic electron data inside of L=15 for all cases examined and at times slightly further out.

5. Summary and Conclusions

The McIlwain L parameter appears to be a useful value for organizing energetic electrons inside of 15 L. The VIP4 and Khurana models use the same internal magnetic field source terms and consequently estimate the same B and L values (within 5%) inside of 15 R_J along the inertial equator. These conclusions serve to motivate future energetic electron modeling efforts that will be used for upcoming missions to Jupiter. Outside of 15 L, the electron environment becomes more difficult to model because the particle motion is more

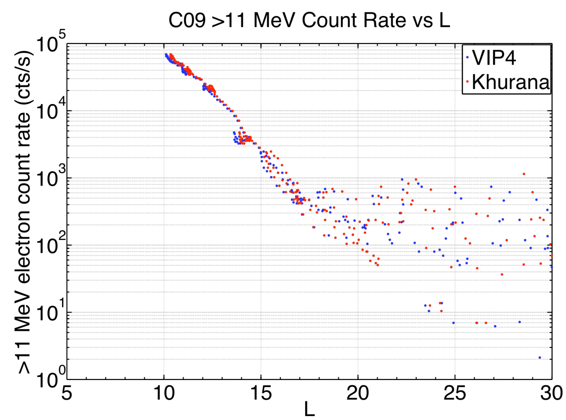

Figure 2: EPD >11 MeV electron count rate during Galileo orbit C09 inbound. Count rate data are plotted as a function of L determined from the VIP4 model (blue) and the Khurana model (red) using the definition of L as defined in eq. 1.

complicated. Careful attention will be needed for any environmental model that spans across 15 L in the inertial equator where azimuthal asymmetries and time-dependent interactions may be very important.

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