Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 48 (2011) 1167–1171
Advances in Space Research (a COSPAR publication)
www.elsevier.com/locate/asr

Rotation of the Earth's plasmasphere at different radial distances

Y. Huang[a,b,*], R.L. Xu[a], C. Shen[a], H. Zhao[a]

[a] State Key Laboratory of Space Weather, Center for Space Science and Applied Research, Chinese Academy of Sciences, Beijing 100190, China
[b] Graduate University of the Chinese Academy of Sciences, Beijing 100149, China

Received 11 April 2011; received in revised form 22 May 2011; accepted 26 May 2011
Available online 31 May 2011

Abstract

We have studied the rotation of the plasmasphere using a large plasmaspheric notch observed by the Extreme Ultraviolet (EUV) instrument onboard the IMAGE spacecraft on 2001/173. The time scale is more than 20 h. On the magnetic equatorial plane the notch extends over more than 1.5 Re in radial distance. By analyzing the brightness for four annuluses at different average values of L from 2.0 to 3.25 over time, we determine the rotation rate of the plasmasphere at different radial distances. The analysis reveals that, with the increase of L, the rotation rate of the plasmasphere tends to strongly decrease on the dusk side and slightly increase on the dawn side.

Keywords: Plasmasphere; Notch; Rotation rate

1. Introduction

The sub-corotation was first observed in the magnesphere of Jupiter (Hill, 1979, 1980). EUV plasmaspheric images from the IMAGE satellite (Burch, 2000; Sandel et al., 2000), provide the possibility to analyze the rotation of the Earth's plasmasphere.

From the EUV images, a variety of plasmaspheric structures have been found (Carpenter et al., 2002; Sandel et al., 2003). One of the largest density structures is the notches, which are characterized by deep density cavities inside the outer plasmasphere. Through tracking a number of notches, Sandel et al. (2003) confirmed that the plasmaspheric departure from corotation with the Earth for the first time. For studying the rotation rate of the plasmasphere, a corotation factor ξ was defined as the ratio of the observed angular rate to the one of Earth's rotation. So, if perfect corotation (or $\xi = 1$) is assumed, the plasma should move 1 h eastward in magnetic local time (MLT) over 1 h of universal time (UT). And they finally found that the corotation factor of plasmasphere in the region from 2 to 4 Re was most frequently from 0.85 to 0.90. Later, Burch et al. (2004) hypothesized that the observed plasmasphere corotation lag was caused by the ionospheric disturbance dynamo. Furthermore, through the study of 18 notches, Gallagher et al. (2005) found most of the cases were observed to corotate lag with the values of ξ between 0.85 and 0.97, except for one case of $\xi = 1$. Besides, the corotation factor ξ can be found by dividing the change in the MLT location of a plasmaspheric feature by the UT elapsed between two EUV snapshots, using a mean-removed cross-correlation of brightness profiles from the plasmaspheric EUV images for different times (Galvan et al., 2008). All those results of the plasmaspheric departure from corotation were reviewed by Darrouzet et al. (2009). Recently, Galvan et al. (2010) calculated the corotation factor of the plasmasphere centered at $L = 2.5$ and $L = 3.5$, and found the rotation rates near dusk were generally lower than those at dawn.

In this paper, we expect that the rotation rate varies with different positions within the plasmasphere, and analyze the variation of the rotation of the plasmasphere for different L-shells and MLT by tracking the position of a large notch.

* Corresponding author at: State Key Laboratory of Space Weather, Center for Space Science and Applied Research, Chinese Academy of Sciences, Beijing 100190, China.
E-mail address: huang_ya2006@yahoo.com.cn (Y. Huang).

0273-1177/$36.00
doi:10.1016/j.asr.2011.05.028

2. Data selection and analysis

The EUV instrument onboard the IMAGE spacecraft is sensitive to 30.4 nm sunlight resonantly scattered by He^{+} ions in the plasmasphere, which observed a large notch with a radial scale more than 1.5 Re in radial distance on 2001/173, and this notch persisted for more than 20 h. Therefore, the notch can be used to study the plasmaspheric rotation for different L-shells and MLT.

Due to the 14.2 h orbit of IMAGE, these data are within two IMAGE spacecraft orbits, and there is a gap between the two orbits when the satellite is within or near the plasmasphere. Hence the time intervals of the two data sets are 02:15–09:25 UT and 16:23–23:13 UT with a time resolution of 10 min. Within these two time intervals, eight images are selected and displayed in Fig. 1. The background of these images has been subtracted, and they have been mapped to the geomagnetic equatorial plane (Roelof and Skinner, 2000; Goldstein et al., 2003; Dent et al., 2003). Based on the fact that the plasmaspheric density falls off rapidly with increasing L and the assumption of dipole coordinates, each pixel in an EUV image can be mapped to the equator along the dipole field line corresponding to the minimum-L touched by its field of view.

In the center of Fig. 1, the two heavy black arcs mark the MLT location of the notch, corresponding to the dusk and dawn sector, respectively. The curved arrow represents the notch moving direction. The two spaces on the day and night side correspond to the times when the IMAGE satellite is near or within the plasmasphere, so the notch's position on the day and night side could not been observed. The eight different positions of the notch are displayed with ①, ②, ③, ④, ⑤, ⑥, ⑦ and ⑧, connecting with lines to its corresponding images. These eight images are arranged counterclockwise. The first four images in the upper part of the figure correspond to UT = 02:46, 04:49, 06:52 and 08:54 with the notch on the dusk side. The others in the lower part of the figure are the notch on the dawn side, and corresponding to UT = 16:44, 18:47, 20:49 and 22:52, respectively. In each image, the direction of the sun is to the right, where the white radial line is the center of the Earth's shadow at MLT = 0 (or midnight), and the black circle is the Earth. Two white circles, with radii equal to 2.0 Re and 3.5 Re in each image, are the boundaries of the image data that we will analyze, and correspond to the scale of the notch.

The appearance of the plasmaspheric departure from corotation is roughly estimated. The minimum value of the average brightness between 2.0 Re and 3.5 Re excluding the Earth's shadow, is taken to be the center of the notch, which is noted with an arrow in each image. The dotted radial line tracks the Earth's rotation, coinciding

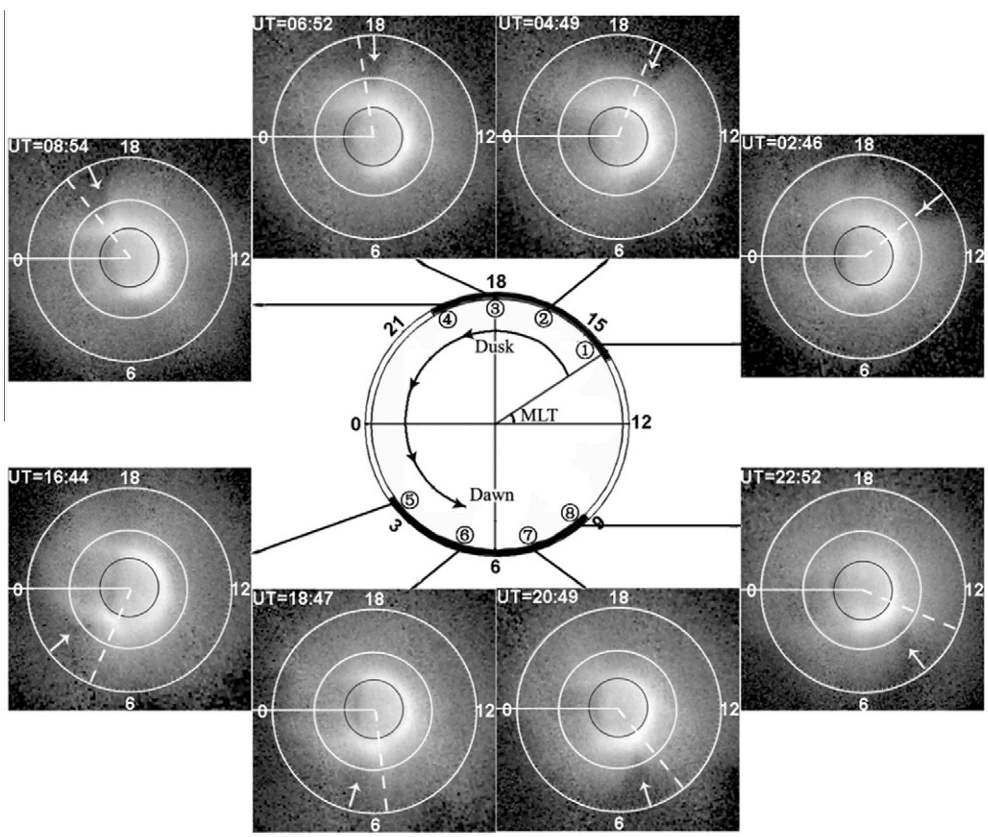

Fig. 1. A sequence of eight plasmasphere EUV images displayed counterclockwise. Each image is mapped to the geomagnetic equatorial plane with the inner and outer white circles corresponding to 2.0 Re and 3.5 Re, respectively. The black circle shows the position of Earth. The center of the notch is marked with an arrow and the radial dotted line tracks the rotation of the Earth. In the center of the Figure, the two heavy black arcs mark the MLT location of the notch and the curved arrow represents the notch moving direction.