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Van Allen Probes 衛星で観測された内部磁気圏における磁場双極子化とイオン加速
Van Allen Probes observations of dipolarization and ion acceleration in the inner magnetosphere

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Recent study employing the MDS-1 satellite reveals that magnetic field dipolarization in the deep inner magnetosphere is not uncommon. When the MDS-1 satellite was located at L=3.0-6.5 near the auroral onset longitude (MLT difference of $\leq$2.5 h), the occurrence probability of local dipolarization was 25%. Surprisingly, an event was found at L$\sim$3.6, far inside the geosynchronous altitude. When dipolarization was found at L=3.5-5.0, magnetic storms were developing. This implies that it is difficult to find dipolarization signatures in the deep inner magnetosphere during a nonstorm period.

We study magnetic field dipolarization and associated ion acceleration in the deep inner magnetosphere, using magnetic field and ion flux data obtained by the Van Allen Probes. First, from the magnetic field data recorded on the nightside (1800-0600 MLT) we selected candidate events in which the magnetic field in the component antiparallel to the dipole axis (i.e., H component in VDH coordinates) increases by more than 20 nT in 5 minutes. Second, the candidate events were scanned visually to confirm if they are accompanied by magnetic fluctuations. Finally, the geomagnetic AL, ASY, and Wp indices were examined to ensure that substorm activity was registered around the candidates events. These procedures yield 96 dipolarization events from 1 October 2012 to 31 October 2013. We find that dipolarization mostly occurs at L=4.5-6.5 before midnight (2100-0000 MLT). Some events are accompanied by O^+ flux enhancements in the energy range of 1-10 keV, which is consistent with the AMPTE/CCE CHEM observation reported by Nosé et al. [2014]. We will discuss possible mechanisms of the selective acceleration of O^+ ions in the inner magnetosphere during dipolarization.

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Van Allen Probes 衛星観測結果に基づく小規模磁気嵐における放射線帯電子フラックス変動のエネルギー依存性についての研究
The energy dependent enhancements of radiation belt electrons during weak magnetic storms: Van Allen Probes observations

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本研究は Van Allen Probes 衛星によるその場観測結果に基づいて、小規模磁気嵐時における放射線帯電子の位相空間密度の時空間変動とその物理過程について議論する。

地球の内部磁気圏には、放射線帯と呼ばれる、相対論的なエネルギーを持つ粒子が地球の磁場に捕捉された領域が存在する。特に電子の放射線帯については、相対論的電子フラックスの典型的な動径分布が、1.5 RE(RE は地球半径) でフラックスが最大となる内帯と、4.0 RE 付近で最大となる外帯とに分けられ、二つのベルト構造を成している。放射線帯外帯電子フラックスは磁気嵐の発生により大きく変動し、磁気嵐の主相においてフラックスは減少することが明らかとなっている。その一方で、回復相でのフラックスの変動に関しては、磁気嵐前より増大する場合、減少する場合、あるいは磁気嵐前と同程度まで回復する場合など、磁気嵐によって異なる様相を示すことが明らかとなっている [Reeves et al., 2003]。主相におけるフラックスの減少は、磁気圏の圧縮に伴う磁気圏界面からの惑星間空間への流出や、プラズマ波動との共鳴によりピッチ角散乱を受けることに起因した大気への降下と消失により説明される。また、回復相でのフラックスの増大は、磁気圏夜側からの動径方向輸送とそれに伴う断熱加速過程と、放射線帯領域で発生するプラズマ波動による非断熱加速過程によると考えられている。これらの過程による相対論的電子フラックスの変動は磁気嵐が小規模 (Dst~-50nT) である場合にも観測されており、小規模な磁気嵐における変動の特徴をより詳しく解析することで、放射線帯全体の変動を理解する上で重要な知見が得られると期待される。

本研究では、2013 年 4 月 24 日に発生した磁気嵐での放射線帯電子の変動を議論する。対象とする期間における Dst 指数の最小値は-50nT である。解析には Van Allen Probes 衛星に搭載された Relativistic Electron-Proton Telescope(REPT)[Baker et al., 2012] と Magnetic Electron Ion Spectrometer(MagEIS)[Blake et al., 2012] による電子フラックス、ならびに Electric and Magnetic Field Instrument Suite and Integrated Science(EMFISIS)[Kletzing et al., 2012] によるプラズマ波動と背景磁場の観測結果、そして位相空間密度の解析に用いる第二断熱不変量 K と第三断熱不変量 L^*は ECT の Science Operation Center で提供されている値を用いた。まず、解析対象とした期間における位相空間密度の動径方向分布について、異なる第一断熱不変量 (μ) ごとに解析を行った。次に、プラズマ波動磁場成分の強度をホイッスラーモード・コーラス放射の典型的な発生周波数範囲であるサイクロトロン周波数の 0.1 倍から 0.5 倍 (0.1fce~0.5fce) の帯域で積分し、波動強度の時間・空間変化と位相空間密度の分布との対応を解析した。その結果、磁気嵐の主相から回復相の初期において、波動強度と位相空間密度の空間分布に対応が見られていることが明らかとなった。また、μ が 3000 MeV/G 以上の値を持つ粒子について、位相空間密度の分布が回復相の中盤 (4/26~) に顕著な変動が見出された。変動量を定量的に検討した結果、L^*=4.6~4.9 において、回復相初期 (4/24 22:00~4/25 02:00) では 1 MeV 程度 ($\mu \leqq 600$) の粒子の位相空間密度は磁気嵐前と比較して 10 倍以上の値を示しているのに対して、2 MeV 以上の粒子の位相空間密度は磁気嵐前より低い値を示しており、しばらく緩やかに増加し、4/26 04:00~09:00 の間で 10 倍程度の急激な増加を示していることが示された。この増加過程を理解するために、イベント発生時の内部磁気圏のプラズマ環境の詳細と、プラズマ波動のスペクトル強度を解析し、特に相対論的電子の加速過程に寄与していると考えられるコーラス放射の波動強度と位相空間密度の対応を議論する。

キーワード: 放射線帯, 磁気嵐, Van Allen Probes, ホイッスラーモード・コーラス
Keywords: radiation belt, magnetic storm, Van Allen Probes, whistler mode chorus

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Occurrence characteristics of relativistic electron microbursts in association with storms and substorms

Occurrence characteristics of relativistic electron microbursts in association with storms and substorms

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Relativistic electron microbursts (REMBs) are short-lived (<1sec), bursty precipitations of relativistic (>1 MeV) electrons observed in the outer radiation belt. REMBs are first reported by the SAMPEX measurements [Nakamura et al., 1995; Blake et al., 1996] and preferentially observed on the dawn side magnetosphere during geomagnetic storms [Nakamura et al., 2000; Lorentzen et al., 2001]. Pitch angle scattering of relativistic electrons by discrete whistler mode wave emissions (chorus) has been considered as the primary candidate for REMBs [e.g., Lorentzen et al., 2001]. Chorus emissions can resonate with not only MeV electrons but also electrons with energies from several to tens keV, leading to diffuse and pulsating auroras [Thorne et al., 2010; Nishimura et al., 2010, Miyoshi et al., 2010]. Since diffuse and pulsating auroras are commonly observed during the recovery phase of substorms, it is expected that occurrence of REMBs depends on the substorm activity. To test the hypothesis, we have investigated occurrence characteristics of REMBs in association with the substorm activity using the data obtained from the SAMPEX spacecraft. Since REMBs are frequently observed during geomagnetic storms, we have also investigated differences of the occurrence characteristics between storm time and non-storm time substorms. We have derived occurrence rates of REMBs in L-value versus magnetic local time domain. AE∗, which is the maximum value of the AE index in previous 3 hours, is used to represent the substorm activity levels. We have defined storm time and non-storm time by using the minimum value of the SYM-H index in previous 2 days. We found that REMBs are most frequently observed during strong substorm activities. The occurrence rates of REMBs do not depend on the levels of substorm activities, although chorus wave intensity increases as the AE∗level increases [e.g., Li et al., 2009]. Comparison of the occurrence rates during storm time and non-storm time substorms for same AE∗levels indicates that REMBs are preferentially observed during storm time substorms. Thus, it is concluded that REMBs most frequently occur during strong substorm activities associated with storms. We will discuss suitable magnetospheric conditions leading to the REMB occurrence considering the configuration of the inner magnetosphere during storm time substorms.

キーワード: relativistic electron microbursts, chorus, SAMPEX, storm, substorm, diffuse aurora
Keywords: relativistic electron microbursts, chorus, SAMPEX, storm, substorm, diffuse aurora

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新たなプロトン放射線帯モデルに基づくあけぼの太陽電池劣化とプロトン被ばく量の関係
Accumulated energetic protons and degradation of Akebono solar cells from a new model of trapped protons

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Output current of silicon solar cells of Akebono satellite orbiting in the inner magnetosphere decreased from 13 A in 1989 to about 7 A in 2009, due to accumulated damage by energetic protons. We worked on modelling of the L-shell distribution of trapped energetic protons which provides best-fit for the degradation of solar cells before 1996, where the correlation is clearly seen. We found that the modeling gives narrower distribution than given by the AP8 and, even, latest AP9 models, but is more consistent with the CRRES quiet model based on the observation before November 1991. Based on our model derived from observations before 1996, we assume a steady state of the proton radiation belt and calculate the integrated proton flux along the satellite orbit up to 2009. In this report, we present the relationship between the integrated proton flux and the degradation of solar cells for long years.

キーワード: プロトン放射線帯, あけぼの衛星
Keywords: proton radiation belt, Akebono satellite

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惑星間空間衝撃波到来時における内部磁気圏イオンのダイナミクス
Impact of interplanetary shock on ions in the inner magnetosphere

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Impact of interplanetary shock on ions in the inner magnetosphere
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Interplanetary (IP) shock is known to redistribute the charged particles trapped in the inner magnetosphere. As for ions with kinetic energy of the order of keV, observations have shown that the enhancement of the ion flux depends on the pitch angle and energy, and that the flux does not always peak at the equatorial pitch angle of 90 degrees after passage of the IP shock. We have performed test particle simulation under the electric and magnetic fields provided by the magnetohydrodynamics (MHD) simulation. The solar wind speed is increased from 372 to 500 km/s in order to reproduce the IP shock. The number density in the solar wind was set to a constant to be 5 cm-3, and the Z component of the interplanetary magnetic field (IMF) was turned from +5 to -5 nT. Just after the arrival of the IP shock, the fast mode wave propagates tailward in the magnetosphere. The amplitude of the electric field exceeds 20 mV/m. We started tracing oxygen ions at (7, 0, 0) Re in the GSM coordinates just before the arrival of the fast mode wave, and reconstructed a phase space density of ions. A summary of the simulation results is as follows. 1) In general, ions with initial pitch angles near 90 degrees are efficiently accelerated, but the degree of the acceleration depends on initial gyrophase, pitch angle, and energy, so that neither the bounce-averaged approximation nor the guiding-center approximation is valid. 2) Ions with small pitch angles are efficiently accelerated when the parallel velocity of the ion is closed to the parallel component of the propagation velocity of the fast mode wave. 3) The phase space density initially given by an isotropic Maxwellian distribution is redistributed to the one that is dominated by the perpendicular component. For initial distribution with temperature of 5 keV, the temperature anisotropy (Tperp/Tpara-1) is increased to 0.33 at an elapsed time of 1 minute from the arrival of the fast mode wave, which may favor the excitation of electromagnetic waves. We will discuss the overall impact of the IP shock on the major ion species in the inner magnetosphere such as protons and oxygen ions, as well as contribution of the electric field that is propagated by way of the field-aligned current and the polar ionosphere.

キーワード: 内部磁気圏, 惑星間空間衝撃波, keV イオン
Keywords: Inner magnetosphere, interplanetary shock, keV ions