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PROBLEM OF ELECTRON DISAPPEARANCE DURING THE MAGNETIC STORM MAIN PHASE: RELATION TO THE DOWN-DUSK ASYMMETRY OF ENERGETIC ELECTRON RADIATION BELT

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Problem of energetic electron - magnetic storm dynamics is a subject of wide discussion by scientific community. Several types of particle losses and accelerations, adiabatic and nonadiabatic results in a radiation belt transformations. Fig. 1 present typical electron radial profiles measured by low-altitude (1000 km) polar orbiter SERVIS-1 before, during and after magnetic storm. At the end of the main phase electron flux at L=3.5-8 decreased to the background level and toward the end of the recovery phase emerged with resulting changes in different radiation belt regions. We will try to approach the problem regarding main phase down - dusk asymmetry of the outer radiation belt.

1. Observations

During the main phase of the magnetic storms a down-dusk asymmetry was observed in magnetic field configuration [*Shi et al, 2006, Tsyganenko, 2002*] and in energetic electron population of the outer radiation belt [*Onsager et al., 2002, Lazutin, 2012*]. Asymmetry registered as the magnetic field and particle decrease at the evening sector was presumably caused by partial ring current.

Fig. 2 presents particle radial profiles measured by low-altitude satellite SERVIS-1, all profiles measured during several hours. Satellite was sun-oriented. Profiles marked by broken lines were measured at the evening sector, while morning ones are shown by solid lines. Similar features were registered during several magnetic storms, where evening profiles were shifted toward lower L as compared to the morning ones.

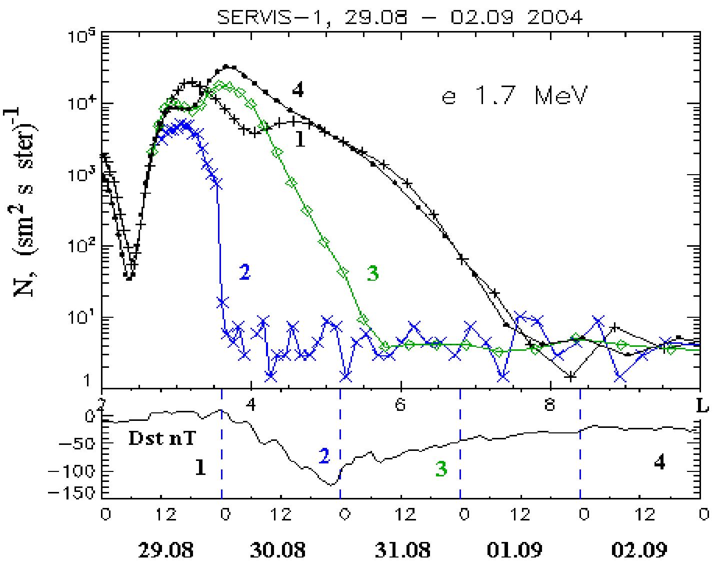

Figure 1. Transformation of the outer belt electron L-profiles during moderate magnetic storm, measured by SERVIS-1 satellite

There are three possible explanations of such asymmetry.

1. Particles became lost at the evening side and new ones were accelerated at the midnight-morning sector. Popular losses mechanisms of outer belt energetic electrons include electron precipitation to the atmosphere caused by increased pitch-angle diffusion [*Fridel et al., 2002, Millan and Thorne, 2007, Shprits et al., 2008, Drew et al., 2012*] and magnetopause shadowing [*for example Ukhorskiy, et al., 2006*]. Shadowing occurs when magnetic field decrease in the inner magnetosphere cause electrons with previously closed magnetic drift orbits transit to the open orbits and became lost at the magnetopause. If we agree that electrons became lost at the evening part of the magnetic drift orbit, we must suppose that each time electron flux became recovered by new acceleration at the midnight-morning part of the orbit. Only that can explain while every time when satellite arrived at the morning sector it encountered recovered particle flux. Particle fast enhancement in the midnight=morning sector of the auroral zone are caused by substorm acceleration during fast activation - dipolarization processes [*Lazutin. 1986 and referenced therein*]. Usual energy of the accelerating electrons are restricted by several hundreds keV, increase of the 1.7 MeV electrons is rather rear occasion. It is impossible to register acceleration of electron flux of MeV electrons so often as shown at Fig. 2.
Therefore suggestion that energetic electrons became lost at the evening sector must be ruled out.

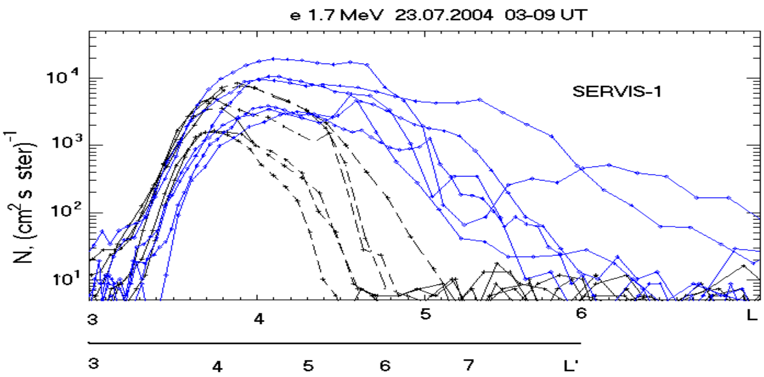

Figure 2. Asymmetry of the radial profiles: low latitude shifts starts earlier and deeply in the evening sector (broken lines) as compared with the morning ones. L' is an approximation for the evening profiles (see text).

2. Real drift L-value. By the upper abscissa axis at Fig. 1 a McIlwain L-value for an undisturbed magnetosphere was taken. During magnetic storms particle magnetic drift trajectory does not corresponds to such L values. For a disturbed part of the magnetosphere corrected L-value must be calculated based on a current local magnetic field configuration.

Therefore if one wants to investigate particle magnetic drift, L-value calculated for the evening sector must differs from the morning one. The evening profile must be shifted to the lower latitudes and possibly for the explanation of observed effects one mast just use different L scales, as shown schematically by the bottom axis at Fig. 1.

We did not know real magnetic field configuration during main phase of magnetic storms. There are models with down-dusk asymmetry, such as *Tsyganenko* [2002], but inevitable deviation from the real one will not allow us to calculate improved L and to found, whether this effect totally or only partially explain observed down-dusk radiation belt asymmetry.

3. Adiabatic transformation. There is another possible explanation of down-dusk effect by simple adiabatic transformation: at evening sector electrons decrease their energy and changes position because of magnetic field decrease while at the midnight-day side it recovers initial position and energy.

Adiabatic effect was described times ago by *McIlwain* [1966] and receive the name "Dst-effect" [*Kim and Chan, 1997; Kim et al., 2010; Lemaire et al., 2013*] consider this effect as a main factor of radiation belt transformation.

Adiabatic effect is based on the condition of conservation of adiabatic invariants. Conservation of the third invariant means that if the magnetic flux inside particle magnetic drift orbit decreased, outward shift of the orbit must follow. Then because of the increase of the length of the magnetic field line mirror points became shifted upward as demands second invariant conservation. And finally conservation of the first adiabatic invariant leads to decrease of particle energy. All that will cause severe decrease of the particle intensities registered by low-altitude satellites. During magnetic field recovery adiabatic recovery of the particle energy and position will return situation to the prestorm condition.

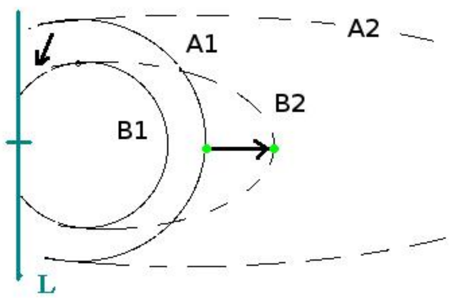

Figure 3. Difference of the particle shifts at low and high altitudes. During magnetic field decrease field lines located on some points at low altitude change equatorial position from A1 to A2 and B1 to B2. Adiabatic cooling results by the particle shift from A1 to B2, with increasing distance from the Earth at the magnetic equator plane and decreasing latitude at the field line footprints [*Lazutin, 2012*].

The same physics may be attributed to single magnetic drift orbit of an electron if magnetic field in the evening sector is decreasing while at the midnight-day side it increased for example due to the enhance solar wind pressure or substorm hyperdipilarization effect [*Lazutin, 2014*]. In such a case electron energy and position will be changing as shown schematically by Fig. 3 for two drift orbits.

2. Discussion and conclusion

Because essential evening side particle loses as a source of the down-dusk asymmetry must be excluded, observed profile differences may be explained by the combination of two other effects discussed above. First effect must decrease asymmetry by the use of a real L' calculated for a magnetic fields distorted at the evening side instead of L-value for undisturbed magnetic field. The second one is an adiabatic effect, namely particle cooling and position shift at the evening part of the magnetic drift orbit and recovery at the morning side.

There are no reason to suppose that outer zone electron variation during the whole magnetic storm differs essentially from the dynamics during the main phase. Adiabatic effects and calculations of exact L values can explain observed variation of the outer electron belt latitudinal profiles.

Real particle dynamics may somehow differ from presented scheme, because some nonadiabatic particle losses and accelerations (injections) can take place, but only as an additional process.

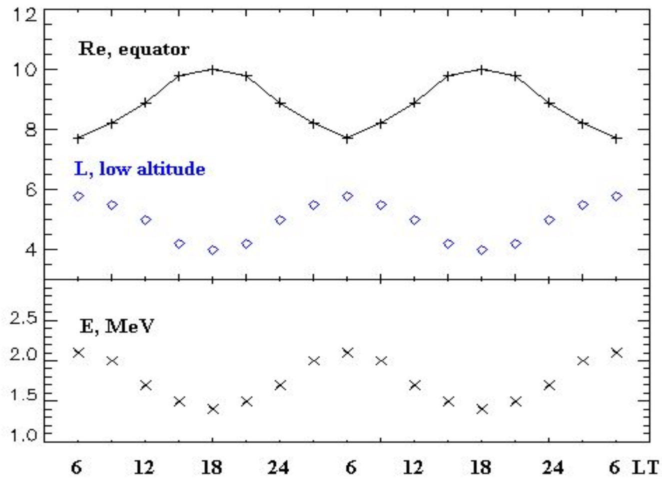

Figure 4. Position of radiation belt electron in the equatorial plane and field line footprint during the evening adiabatic cooling and morning recovery and particle energy (bottom section).

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