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SAR-ARC CHARACTERISTICS IN THE REGION OF RING CURRENT DISSIPATION AND DURING POLARIZATION JET DEVELOPMENT

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Abstract

Electron temperature variations measured by AUREOLE 3, DE 2, COSMOS 900 and INTERCOSMOS 24 in the F – region of the ionosphere during different phases of magnetospheric disturbances are analyzed and classified. (1) Intense electron heating up to 6000 K and higher inside the latitudinal band of 4 – 8 degrees is connected to ring current energy dissipation and is observed during recovery phase of large magnetic storms. This electron heating causes the formation of classical SAR-arcs. (2) In other structures of 1 – 2 degrees latitude width electron temperature is enhanced up to 3000 – 3500 K. Formation of these structures is associated with initiation of substorm activity and can coincide with a start of storm main phase. In these structures the frictional heating of plasma due to strong electric field is operated.

Introduction

Significant heating of ions in the F-layer by collisions with neutrals in the polarization jet region and accompanying processes: changes in ion composition and an increase of recombination rate, electron heating, lead to the excitation of red oxygen line 630 nm and to the appearance of a weak SAR-arc (Foster et al., 1994, Alexeyev et al. 1994). This arc differs in its physical nature from the "classical" SAR-arc appearing at decay phase of a magnetic storm where no visible increase of electric field was observed (Kozyra et al., 1997). The intensity of weak PJ-induced SAR-arc, which are often observed in the night sector, is not high and equals, as a rule, ≤300 rayleigh. It is understandable, since the electron density in the PJ region is significantly lowered, and electron temperature is enhanced, but not so higt, as in the powerful "classical" SAR-arc observed during the IGY. It is clear that relatively frequent weak SAR-arc associated with PJ essentially differ from the "classical" SAR-arc (Khalipov et. al., 2001). Detailed and complete measurements during a magnetic storm, concerning a SAR-arc with an intensity of up to 300 rayleigh, wich was considered as an example of "classical"SAR-arc, were analyzed in (Kozyra et al., 1997). It was shown that at rather intensive injection of energetic ions into the plasmasphere down to a level where the electron density was equal to ~ 500cm^{-3}, only Coulomb collisions with ions of ring current were sufficient for electron heating and excitation its luminescence. However, this result also implies that excitation of luminescence of powerful "classical" SAR-arcs (whose intensity can be higher by an order of magnitude or even more) is possible only as result of more effective mechanism (or mechanisms) of electron heating and/or acceleration.
Present paper considers distributions of electron temperature T_e and density N_e in the subauroral ionosphere F region observed simultaneously with typical red arcs and during SAR-arcs associated with polarization jet development.

Experimental results

More than 150 cases of satellite measurements of thermal plasma parameters in the ionospheric F – region during magnetically disturbed conditions were analyzed. Two specific geophysical situations when electron temperature T_e is significantly increased were found.
Fig. 1 illustrates the first situation, which is connected with ring current energy dissipation and is associated with "classical" scenario of upper ionosphere heating and SAR-arc appearance. Fig. 1 shows that AUREOLE 3 measurements referred to recovery phase of magnetic storm of medium intensity on February 21 – 25, 1982. In a wide band of subauroral latitudes 50-57.5 Λ_0, the electron temperature is enhanced up to 3000-3500 K and the electron density is slightly depressed.

Similar event was observed on October 14, 1981 during strong magnetic storm, Dst – index was -133 nT at 07.00 UT. At the recovery phase at 14.18 – 14.20 UT the DE 2 satellite recorded the electron temperature increase up to 5800° K in the wide range of invariant latitudes 53 – 61° Λ_0, while the electron density was 2 – 3 times decreased.

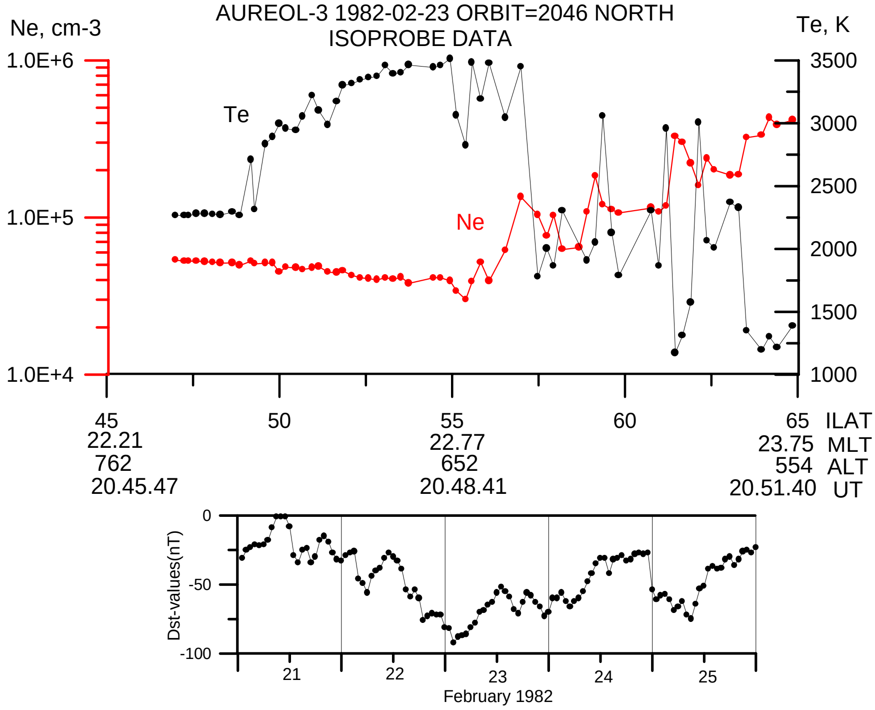

Fig. 1 Measurements of the electron density and temperature on the AUREOL-3 satellite during recovery phase of magnetic storm on February 23 1982.

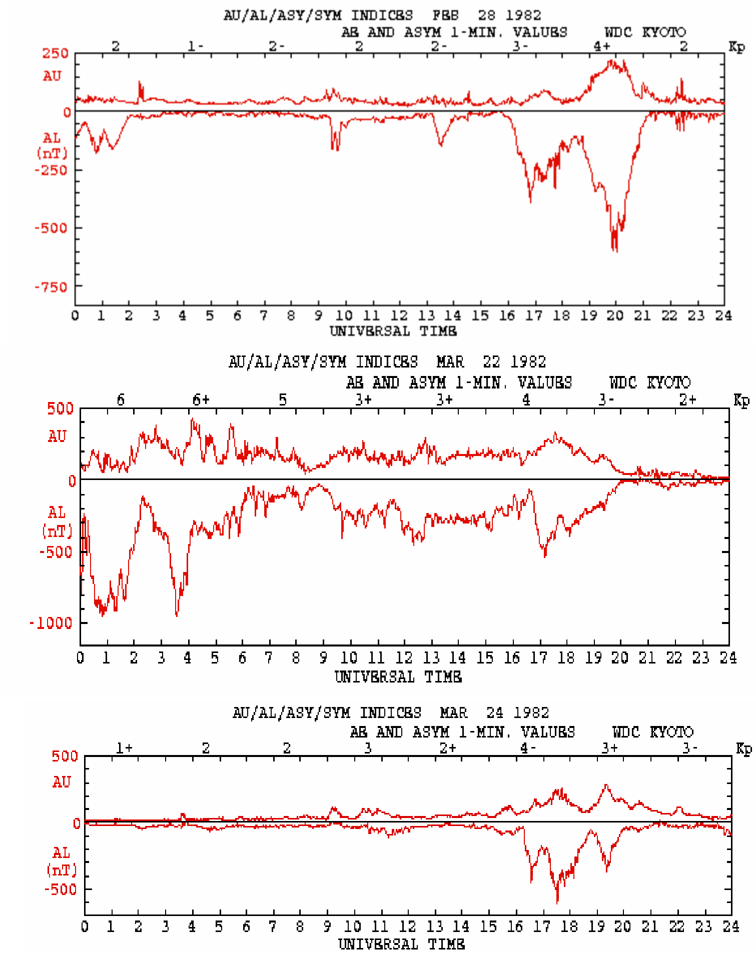

Fig. 2 Auroral activity variations during the AUREOL-3 measurements on 28 February 1982, 22 March 1982, 24 March 1982

Analogous example can be found in the paper by Craven (1982). SAR-arcs with latitudinal extent of ~4° and intensity of ~ 1 kR were observed by the DE 2 photometer in the recovery phase of magnetic storm on October 21, 1981 (minimum Dst was -200 nT). Chandra (1971) presented the OGO 4 data showing the wide band of increased electron temperature in the recovery phase of magnetic storm on September 29, 1967. In absolutely different geophysical situation, latitudely narrow electron temperature enhancements are recorded in subauroral latitudes, and these temperature peaks are associated with polarization jet (PJ) development. These events are connected with substorm activations. Figure 2 shows that subauroral peaks are observed at AE burst. The narrow T_e – peaks are often observed without magnetic storm development.

Let us consider some events in details. On February 28, 1982 the narrow peak of enhanced temperatures extends over ~ 1.5° (Fig. 3). In the figure the arrow marks the location of equatorward boundary of diffuse precipitations determined by the AUREOLE-3 spectrometer. It is seen that this boundary location exactly coincides with the location of polar edge of the main ionospheric trough. The value of Dst was – 14 nT at that time. Figure 2 shows that the measurements were done after the intense substorm disturbance. Magnetic storm was not observed. Very similar structure of subauroral T_e – peak was observed on March 22, 1982 (Fig. 4), while the peak electron temperature was significantly higher – 4000 K. Dst index was –21 nT during the observations, and a small magnetic storm with minimum Dst of –55 nT occurred before.

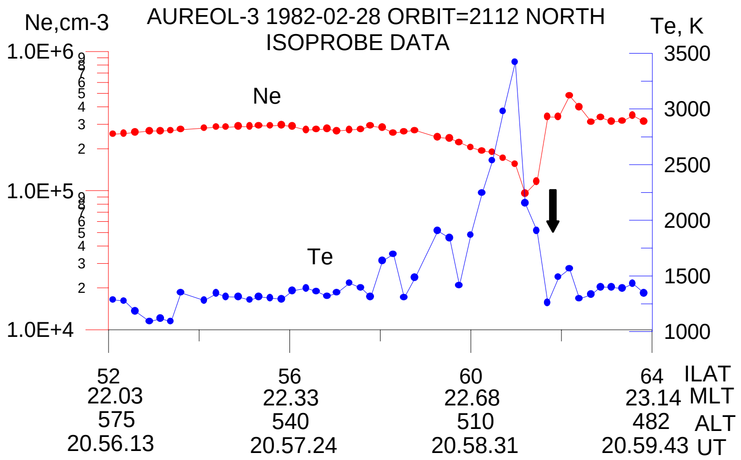

Fig. 3. Specific structures in distributions of electron density and temperature observed by AUREOL-3 in polarization jet band on 28.02.1982. Arrow marks the location of equatorward boundary of diffuse auroral zone.

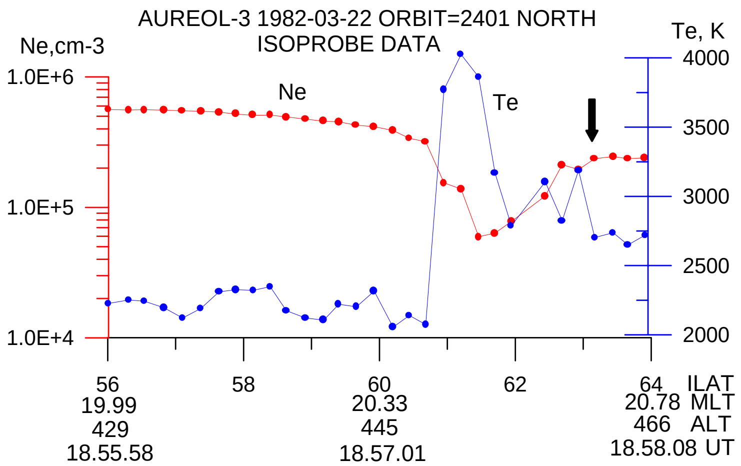

Fig. 4. Specific structures in distributions of electron density and temperature observed by AUREOL-3 in polarization jet band on 22.03.1982. Arrow marks the location of equatorward boundary of diffuse auroral zone.

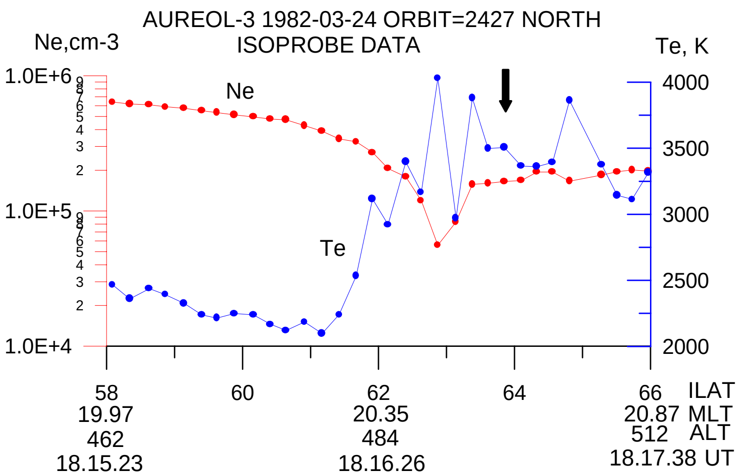

Fig. 5. Specific structures in distributions of electron density and temperature observed by AUREOL-3 in polarization jet band on 24.03.1982. Arrow marks the location of equatorward boundary of diffuse auroral zone.

On March 24, 1982 (Fig. 5) the AUREOLE 3 data were obtained just above the ionospheric stations in Arkhangelsk. The distribution of electron density reduced from satellite and ground-based measurements were analysed in details by *Benkova et al*. (1985). It was shown that the narrow trough in electron density observed by the satellite is associated with the structure of PJ recorded by ground-based ionosondes. Dst index was +14 nT at the time of the measurements. Magnetic storm was not observed.

Afonin et al. (2000) performed a detailed comparison of optical, ground-based ionospheric, and Intercosmos 24 measurements of electron density and temperature in the PJ band. It was found that the PJ development is accompanied by the appearance of SAR-arc with the intensity of 200 – 300 R.

To conclude, the SAR-arcs associated with PJ development is advisable to single out in a separate class of optical phenomena. Particularly this separation is absolutely necessary for studying statistical dependencies. The main differences between these two SAR-arc types are shown in Table 1.

Table 1. The comparison of classical subauroral red arcs (SAR-arcs) with those connected with polarization jet

Characteristics	Classical SAR-arc	SAR-arc connected with PJ
Appearance conditions	Recovery phase of strong magnetic substorm	Substorm
Intensity 630 nm	I_0 ~ 0.5-10 kilorayleigh and more	I_0 < 500 rayleigh
Lifetime	Up to tens of hours	~ 2 – 5 h
Width (in latitude)	300 – 800 km	50 – 200 km
Length (in MLT)	Along entire L-shell	~18-02 MLT or less
Electron temperature above F2 peak	3000-10000 K	3000 – 5000 K
Source of heat	Energetic ions of ring current	Collisions of quickly drifting F-layer ions with neutrals
Electric field	None	50 – 200 mV/m

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