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Sessions I - IV

STABLE AURORAL RED ARCS AND POLARIZATION JET: CASE STUDY AND STATISTICAL COMPARISON

V.L. Khalipov[1], Yu.I. Galperin[2], V.N. Alexeev[1], V.V. Afonin[2], O.S. Akentieva[2], I.B. Ievenko[1] and A.E. Stepanov[1]

[1] *Institute of Cosmophysical Research and Aeronomy, Lenin Ave. 31, Yakutsk 677891, Russia.*
[2] *Space Research Institute of RAS, Profsoyuznaya ul, 84/32, Moscow 117810*

1. Introduction.

Coordinated measurements of thermal plasma characteristics in the region of Stable Auroral Red Arcs (SAR-arcs) shows that SAR-arc formation in the dusk and near midnight sector occurs simultaneously with the development of Polarization Jet (PJ), and these phenomena spatially coincide [1,2]. On the one hand this experimental result evidences that the process of SAR-arc generation is initiating in the ionosphere modified under the action of strong electric field of PJ (E ~ 100 mV/m). On the other hand such a powerful source of energy ~ 0.5 erg/cm^{2}s or more [3] is enough for initiating a selective emission in a line 630.0 nm with the intensity of hundreds of Releys.

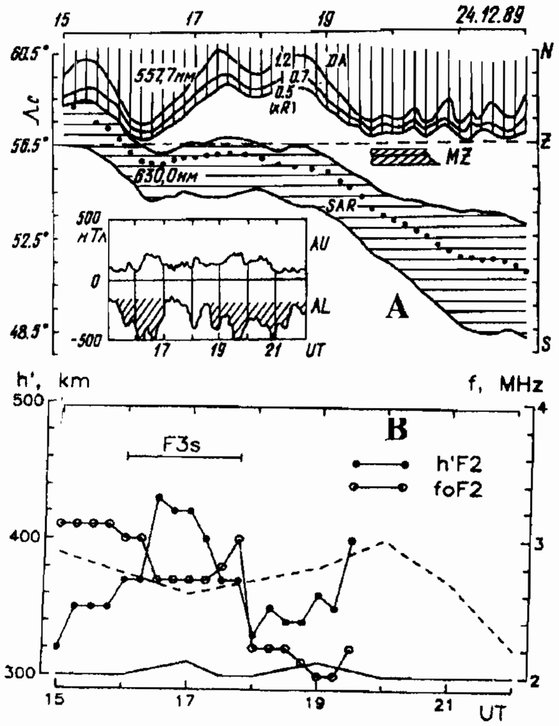

Fig. 1 a –Latitude profiles of constant intensity (marked in kR) of diffuse auroral emission of 557.7 nm and the SAR arc on Dec. 24, 1989 as measured by the photometer. Dotted line refers to maximum SAR arc intensity Dashed line marks the location of the station of optical observations and MZ denotes the magnetic zenith of the station. Additional window shows variations of geomagnetic indices AU and AL. **b** – Time variations of the parameters of F2 layer measured by ionospheric station in Yakutsk. Solid and dashed lines present the layer height and its critical frequency on the closest unperturbed day. Lines with full and empty circles show these parameters during the SAR arc observation.

Simultaneously the interrelation is unclear of considered type of SAR-arcs with classical stable red arcs, which were numerously observed during IGY and later on were analyzed in a review [4]. It is worth noting here that a SAR-arc can be associated with so called 'nose events' – impulse injections of low energy H^+ ions (~10-30 keV) with pitch angles close to 90° into the inner magnetosphere [5]. The development of partial ring current during nose-events was analyzed in details using the data of Explore 45 [6]. It was shown that these events are associated with substorm activity and are observed predominantly in the time sector of 15-23 MLT with a maximum at 20 MLT on L-shells ~ 3-4. PJ events have similar spatial – time distribution [7]. In the present paper a connection of SAR-arcs and PJ with substorm activity is studied using a large number of measurements in 1989 – 1992. Additionally ground-based optical observations of SAR-arcs and ionospheric parameters at meridian of Yakutsk (λ = 130°E, 2.5 < L < 4.2) and simultaneous measurements of the ion density and electron temperature on board the INTERBALL 2 and AKTIVNY satellites are analyzed.

2. Instrumentation.

The satellite IC 24 was launched on September 28, 1989 into an orbit with apogee of 2500 km and perigee of 500 km. Ion temperature and electron density were provided by the Faraday cup with retarding potential. Electron temperature of cold plasma onboard Auroral Probe of Interball mission was measured by floating probe modification of Langmuir probe (experiment KM-7). The optical data were obtained by the Maymaga station situated 100 km northward of Yakutsk. SAR arcs were observed by 2-channel scanning photometer with the angle of the field of view ~ 3°. Distribution of emissions on wavelengths λ = 630 nm and 557.7 nm were recorded along the geographical meridian every 2 min. Characteristics of the ionosphere were provided by vertical and oblique backscatter sounding every 15 minutes from the stations in Yakutsk (Λ_0 = 55.6) and Zhigansk (Λ_0 = 60.4). The local time (LT) at the meridian of ground-based observations LT = UT + 9 hours.

3. Observations

In the ionosphere signatures of polarization jet were studied in details with the data of Yakutsk ionozond chain and simultaneous satellite data [8]. Development of PJ close to the zenith of an ionospheric station causes a formation of additional traces on ionograms ($F3_S$ –reflections) due to rapid (15-30 min) electron density decrease in ionosphere F-region. Fig.1 presents example of the SAR-arc and PJ development when the magnetic activity was high. Through the period of observations and preceding 6 hours the geomagnetic activity indices K_p = 4 and D_{st} = -18 nT. The starting of SAR arc formation was monitored at 15.00 UT after the beginning of the substorm 'break up' phase at 14.04 UT. SAR arc had an intensity of 200 R and adjoined directly to the equatorward boundary of the diffuse auroral emission. At 15.54 the second substorm onset occurred and the SAR arc emission intensified from 200 to 400 R during 20 min. Through the time interval 16.15 – 18.30 UT the SAR arc intensity peaked nearly at Yakutsk latitude, and then the arc moved continuously southward with the velocity ~ 40 m/s. The F2 layer started to rise at 15.15 UT and at 16.30 UT h'F2 was 130 km higher, than its undisturbed value. Approximately in 15 min. after the SAR arc displacement to the zenith of the Yakutsk station, $F3_s$ reflections specific for the polarization jet formation appeared in the ionograms. At 19.45 UT the diffuse aurora boundary moved to Maymaga station and the ionograms detected reflections from the regions of enhanced electron density on the poleward edge of the main ionospheric trough.

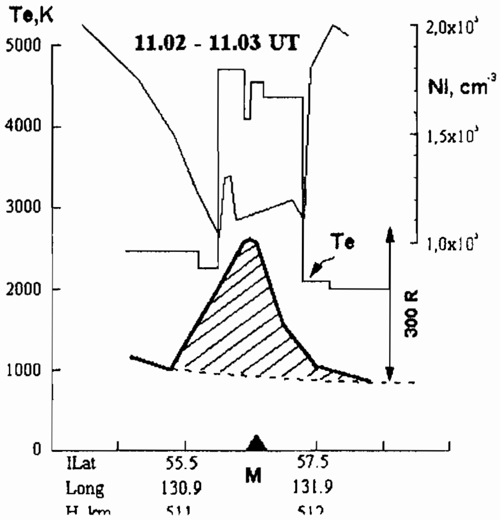

Fig.2. Latitudinal profiles of elecrton temperature, electron density and 630 nm emission intensity in SAR-arc on December 2, 1989.

The variations of ionospheric parameters in the SAR arc region were also checked in details for a set of other 53 events using the observations at Zhigansk station. They also demonstrated the close relationship of the SAR arc and polarization jet phenomena in the dusk and near midnight sectors.

An example of satellite and ground-based measurements in the SAR-arc region in the evening sector on 2 December 1989 is shown in Fig.2. SAR-arc was close to the zenith of the station for optical observations, its maximal intensity achieved 300 R, and latitudinal extent was ~ 2°. The PJ structure appeared at 09.45 UT (18.45 LT) as observed by the Yakutsk station and it was continuously observed during the satellite pass by. At the height of the F-region maximum (h_m ~ 400 км) at the bottom of the trough was observed to be $1.8 \cdot 10^5$ $см^{-3}$, and at the equatorward wall of the trough it was equal $2.9 \cdot 10^5$ $см^{-3}$.

The Intercosmos-24 masurements within the December 2, 1989 SAR-arc were made at 11.02 UT at the altitude ~ 510 км at the ground station meridian. The electron density over the arc was depressed by about 2 times, and T_e have rised to ~ 4600° K. It The region of enhanced intensity of 630 nm emission was observed to be coincident in latitude with well defined depletion in ion density and enhanced Te values were observed at the bottom of the N_i trough. According to the satellite measurements over SAR-arcs on three other days at ~ 500 km N_i was decreased by 3 - 5 times, and T_e was elevated to 4500 – 4700° K. The measurements at different altutudes in similar geophysical conditions give evidence to significant rise of T_e with altitude.

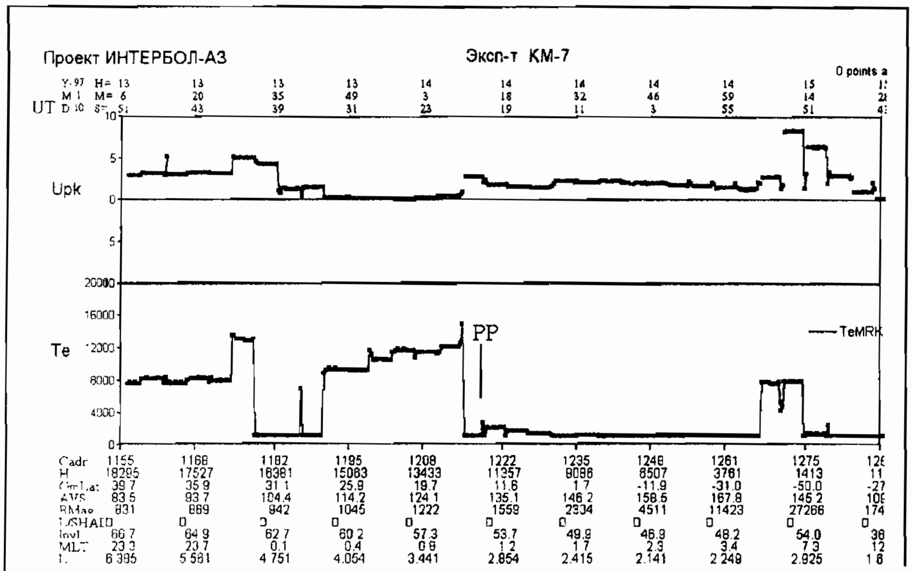

Fig.3. Measurements of electron temperature at Interball-2 during development of SAR-arc on January 10, 1997..

The data obtained from INTERBALL 2 on January 10, 1997, when the SAR-arcs were observed by Maymaga sta-tion from 10.10 UT till 15.00 UT are shown in Fig.3. In the Southern hemisphere at the invariant latitudes con-jugate to the SAR-arc location a sharp elec-tron temperature peak is observed with T_e ~ 7800 K. Simultaneo-usly in the Northern hemisphere it appears as T_e enhancement in the invariant latitu-de range 54.5° – 55.5°. Plasmapause was located at L ~ 3.0 as observed by the instrument ALPHA 3 on INTERBALL 2. Similar peaks in T_e on different height levels were observed in 6 more cases of complex measurements.

Rather large statistics of the time moment of PJ appearance according to the data of Yakutsk ionospheric station (91 events) was used for comparison with the moments of substorm activization (Fig.4) in the conditions of AE ≥ 500 nT. The level of 500 nT was chosen empirically. Beginning with it PJ can be recorded by Yakutsk station. More than a half of the events are accompanied by the SAR arc observational data. A very high correlation is seen between the considered phenomena.

4. Discussion.

Undoubtedly the characteristics of SAR-arcs which coincide with PJ appearance, their intensity and spatial position, permit to include them into a set of 'classical' events. Meanwhile their development is not tied to the recovery phase of magnetic storm, but occurs during the substorm activization. PJ appears in time sector 18 – 02 MLT and its lifetime is 2-3 hours, but the created trough structure exists during hours in the dark ionosphere. Such a distinct structure channels the 630.0 nm emission, which is caused by the ring current energy input.

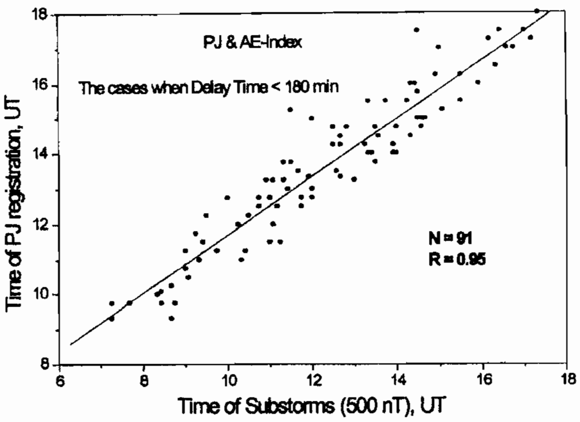

Fig.4 The time of PJ appearance above the Yakutsk station versus the time of the development of substorm activity with AE > 500 nT.

Also in the SAR-arcs additional processes develop and their physical nature is still unclear. Significant fluxes of electrons with the energy of some eV are observed, and they permanently exist above the SAR-arc and essentially contribute to the exciting of 630.0 nm emission [9]. It is probable that the origin of these field –aligned electron fluxes is associated with the intense frictional heating of ions in PJ region and their lifting to high altitudes that would cause the appearance of positive charge there. It is worth to stress here that the temperature peak above the SAR-arc is much more pronounced on the heights < 0.5 R_E than on the heights > 1R_E.

References:

1. **Alexeev, V.N., V.L. Khalipov, I.B. Ievenko, and V.M. Ignatyev,** Geomagnetism, Agronomy and Physics of the Sun, Moscow, Nauka, **93**, 143-152, 1991.
2. **Foster, J.G., M.J.Buonsanto, M. Mendillo, D. Notingham, F.J. Rich, and W. Denig**, Coordinated stable auroral red arc observations: Relationship to plasma convection, *J. Geophys. Res.*, **99**, 11429-11439, 1994.
3. **Sellek, R., G.J. Bailey, R.J. Moffet, and P.C. Anderson**, Effects of large zonal plasma drifts on the subauroral ionosphere, *J. Atmos. Terr. Phys.*, **53**, 557-565, 1991.
4. **Rees, M.H. and R.G. Roble**, Observations and theory of the formation of stable auroral red arcs, *Rev. Geophys. & Space Phys*, **13**, 201-241, 1975.
5. **Kozyra , J.U., M.O. Chandler, D.C. Hamilton, W.K. Peterson, D.M. Clumpar, D.W. Slater, M.J. Buonsanto, and H.C. Carlson,** The role of ring current nose events in producing stable auroral red arc intensification during the main phase: observations during the September 19-24, 1984 equinox transition study, *J. Geophys. Res.*, **98**, 9267, 1993.
6. **Ejiri, M., R.A. Hoffman, and Paul H. Smith,** Energetic particle penetrations into the inner magnetoaphere, *J. Geophys. Res.,* **85**(A2), 653-663, 1980.
7. **Galperin, Yu. I., L.D. Sivtseva, V.M. Filippov, V.L. Khalipov,** Subauroral upper ionosphere, Novosibirsk, Nauka, 1990.
8. **Galperin, Yu. I., V.L. Khalipov, and V.M. Filippov**, Signature of rapid subauroral ion drifts in the high-latitude ionosphere structure, *Ann. Geophys.*, **4**, 145-153, 1986.
9. **Slater, D.W., C. Gurgiolo, J.U. Kozyra, E.W. Klekner and J.D. Winningham**, A possible SAR – arc energization source: precipitating electrons, *Adv. Space. Res.*, **6**(3), 133-137, 1986.