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Comment on 'Magnetospheric source region of discrete auroras inferred from their relationship with isotropy boundaries of energetic particles' by A. G. Yahnin *et al.*

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The purpose of this comment is to clarify our views on the mapping problem incorrectly presented in the work by Yahnin *et al.* (1997) (hereafter, Y97), and also to indicate some difficulties in this study which can lead to further misunderstanding of this and related problems.

In Y97 case studies are described of relative positions of discrete auroral arcs from ground-based all-sky camera data, and low-altitude satellite data on energetic particle isotropisation boundaries (IB) measured by the similar TIROS satellites NOAA-6 and NOAA-7. On this basis they attempted to compare some schemes of mapping the magnetospheric plasma domains, and in particular, the central plasma sheet (CPS) with its neutral sheet (NS), and the plasma sheet boundary layer (PSBL) in the tail, to different regions of the nightside auroral luminosity.

We cannot agree with the formulation in Y97 of our mapping concepts and scheme, which were described in several papers, in particular, in Feldstein and Galperin (1985, 1993) (further, FG85 and FG93), and Galperin and Feldstein (1991, 1996) (further, GF91 and GF96). Consequently, we must clarify the difference between our mapping scheme and that of Lyons *et al.*, (1988) and Lyons (1992) as was described in Y97 in their Discussion section. In page 956 of Y97 we read: …in contrast to the view of Feldstein and Galperin, and in agreement with the findings of Elphinstone *et al.* (1995), discrete arcs are sometimes found at high latitudes, very close to the sharp decrease in the electron energy flux which is certainly related to the outermost part of the plasma sheet…'. This statement is not only wrong, it is internally contradictory because it claims that, according to our view, the polar part and the boundary of the *oval of discrete auroral forms* (in particular, and rather often, auroral arcs) do not contain discrete arcs! We can only remind readers of our papers, those cited already and others on the subject, where during moderate and active conditions *the whole length of the auroral oval of discrete forms*, from its inner boundary-equatorial auroral arc, as far as its outermost part, is projected to the tail current sheet. We are sure that our texts are clear enough on this issue as can be seen by their analysis by other researchers (see e.g., Hones *et al.*, 1996). It was indeed surprising to read about such a 'contrast' in the Discussion section of Y97 while even in their Introduction section (page 944) it is correctly stated that in the papers FG85 and GF91 we have 'mapped the discrete participation into the rest of the plasma sheet, situated tailwards of the trapping boundary…'.

This misconception is further developed by Y97 in their Fig. 4 which was intended to schematize the difference noted, or 'contrast'. In particular their Fig. 4b entitled 'After Feldstein and Galperin (1985)' does not represent our view as is claimed in Y97. Our own scheme of our concepts that summarize the dynamics of magnetospheric structure between very quiet and strongly disturbed conditions was published in FG93 as Fig. 7 exactly in the same format as in Fig. 4 in Y97. Astonishingly, instead of using this figure, Yahnin *et al.* (1997) made another one which misinterprets our results. To demonstrate this we reproduce here Fig. 1 together with Fig. 7 from FG93, and Fig. 4 from Y97. In the figure schematic 2D cross sections of the magnetosphere are shown (not to scale) for the midnight meridian.

It can be seen that in our real scheme, during extended, very quiet intervals, the equatorial steady auroral arc of the oval is located at, or close to, the stable trapping boundary for energetic electrons. Thus it projects as far as, or close to, the inner edge of the cross-tail current in the plasma sheet while the rest of the plasma sheet till the distant neutral line (DNL) projects to the polar diffuse auroral zone (PDAZ). Our scheme also includes the change in the magnetospheric structure during disturbed periods or magnetospheric substorms. During moderately strong disturbance the *whole* widened near-midnight auroral oval of discrete forms projects to the tail current sheet from its inner edge (often projected to an equatorial arc) to the new neutral line (NNL), or a plasmoid. The NNL probably corresponds to an active intense polar auroral arc, or band, at the polar auroral bulge, or polar edge of the oval. The

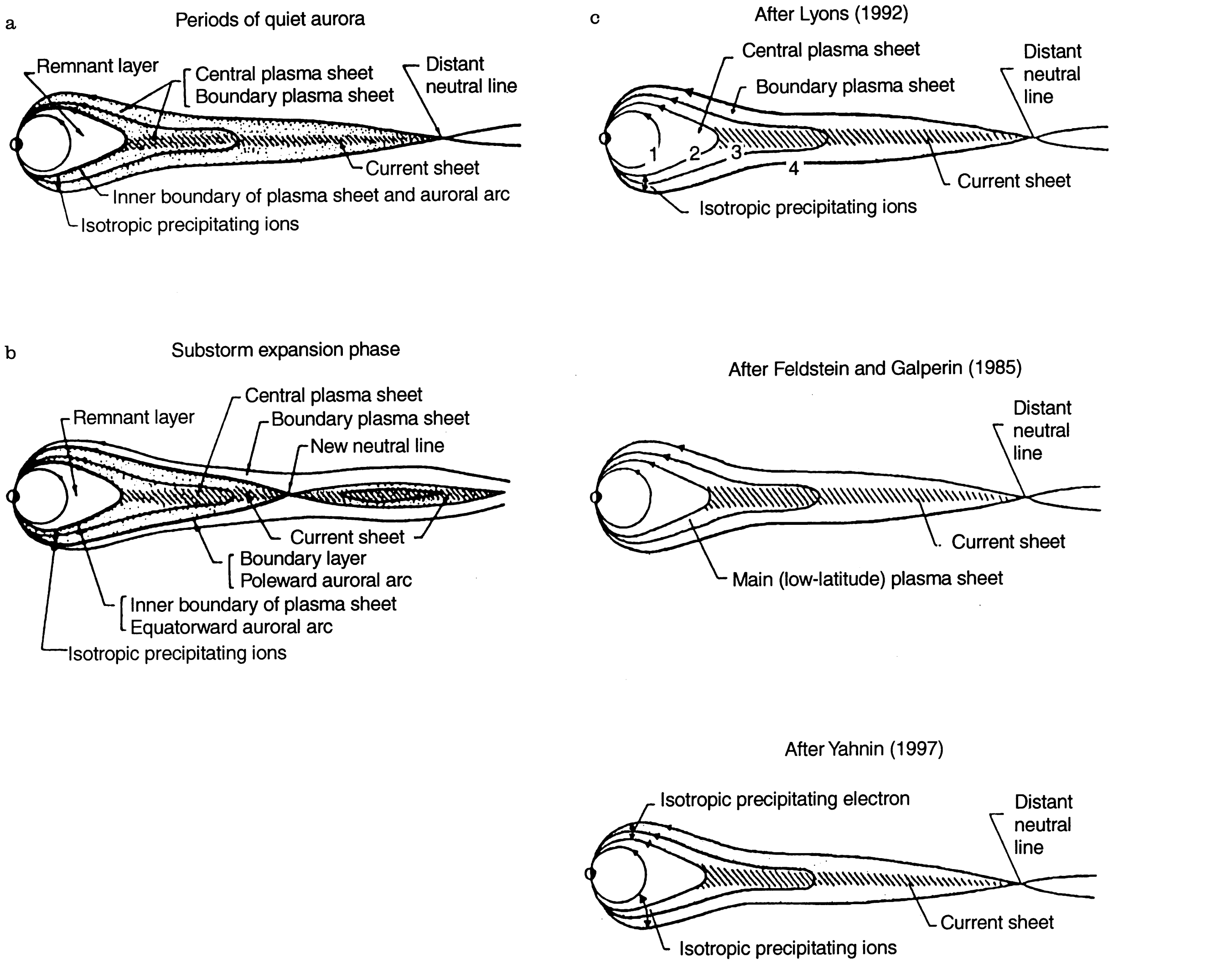

Fig. 1a–c. Schematic presentation (*not to scale*) of the magnetospheric tail plasma domain for the midnight meridian cross section and some structural features of the magnetotail, **a** in the interval of quiet auroras and **b** during substorm expansion phase according to Feldstein and Galperin (1993). **c** Schematic presentation of different views to the source region of auroras from Yahnin *et al.* (1997). *Field line 1* is a dipole-like magnetic field, *line 2* corresponds to inner edge of the current sheet, *line 3* corresponds to inner edge of PSBL, and *line 4* marks the outer edge of the plasma sheet

PDAZ is also present during moderately disturbed periods, but shrinks in latitude. Its projection to the plasma sheet can extend as far as the DNL (see discussion later in the text). During the expansion phase maximum, the bright auroral band, considered to be the projection of the DNL, can be at the polar cap boundary, so that the PDAZ shrinks, or temporally disappears (Feldstein and Elphinstone, 1992). Apparently the existence of the PDAZ adjacent to, but poleward from the oval of discrete forms, was not recognized in Y97 (see later).

We may remind readers that there exists a really important contrast between the scheme advocated by Lyons and his co-workers, as well as by some other researches (it is reproduced in Y97 in their Fig. 7 in its upper part, and again here in Fig. 1), and the scheme advocated by us. This contrast lies in the projection of the nightside auroral oval to the tail: to the PSBL according to the former scheme, and to the CPS according to ours. This mapping is critical for the implied location of the equatorial arc projection in the tail plasma sheet and thus of the auroral substorm onset region in the magnetosphere. In the former scheme it was supposed to occur at distances ~50–100 R_e, i.e. in the distant tail, and thus is related to the PSBL. In our scheme this distance, from many arguments, was evaluated as located somewhere between ~5–15 R_e (depending on activity level), i.e. near the inner boundary of the tail current sheet which we identify with the inner boundary of the CPS (FG85, CF91). This latter view (not entirely new, see FG85) is now confirmed by multitude of in situ measurements and apparently is fully accepted by the magnetospheric community (see Kennel, 1992, 1995).

Another difficulty in Y97 concerns the relative position of the bright auroral arc, or band, at the oval polar boundary, and the VDIS-2 events (velocity dispersed ion structures of type 2) discovered by

Kovrazhkin *et al.* (1987), and Zelenyi *et al.* (1990) at the polar edge of the auroral precipitation, or the polar cap boundary. Y97 claim on page 944 that bright polar auroral arc collocates with VDIS-2, and build their interpretation on this premise. Here their neglect of the existence of the PDAZ is crucial. This structural part of the auroral luminosity was discovered and studied by Yevlashin (1961, 1964, 1968), Eather (1969) and Eather and Mende (1972) from ground optical observations; by Whalen *et al.* (1977), from airborne auroral observations. Then it was analyzed in detail from satellite soft electron spectral measurements as a distinct structural feature in auroral precipitation by Valchuk *et al.*, (1979) and by other researchers (see detailed discussion in FG85, GF91 and Newell *et al.*, 1996 for quantitative definitions). It will be interesting to see how long it will take for Yahnin *et al.* (1997) to assess the existence and significance of the PDAZ poleward from the oval of bright discrete forms, the finding of which their own Polar Geophysical Institute played the leading role.

One case where the two structural features, the polewardmost bright auroral acr, and a VDIS-2 structure, were supposed to overlap, indeed was noted in Elphinstone *et al.*, (1995), but it is by no means typical. Observations from the AUREOL-3 show that the VDIS-2 structures overlap with the PDAZ, not with the polar bright auroral band. Detailed statistical results on VDIS-2 structures (99 cases) were presented by Bosqued *et al.* (1993) (see especially their Fig. 6). They show that a VDIS-2 structures "is always observed poleward of and adjacent to the region of discrete electron precipitation" (page 19187). In average the VDIS-2 structures are located within $\sim 1°$ of latitude inward from the polar cap boundary, but *the average location of the polewardmost inverted-V is still further* 1–2° *equatorword.* Similar results were published from several other satellites (See, for example, Saito *et al.*, 1992, from AKEBONO, de la Beaujardiere *et al.*, 1994, and Sotirelis *et al.*, 1997 from DMSP). This means that typically the VDIS-2 lies *outside* of the oval of discrete forms, as was described, for example, in GF91.

These data, to our view, are inconsistent with the neglect of the PDAZ at the times of VDIS-2 presence in the "new" scheme proposed in Y97, and with the collocation of VDIS-2 with the polewardmost auroral arc, or band, as was supposed in Y97. Also they missed the PDAZ in their presentation of our results. The NOAA satellites particle data, through not fully presented in Y97, seem to be consistent with the appearance of the PDAZ, or the soft zone, in the cases considered.

It seems to us not less significant that in many cases the VDIS-2 structures, if interpreted as the velocity-filter effect from a point source in a constant electric field, have their extrapolated origin(for infinite velocity) just at, or near, the polar edge of the PDAZ, i.e. at the polar cap boundary (see, GF91, GF96). This could imply widely different radial distances to the origin in the far tail of the bright polar auroral band and of VDIS-2, and thus their different sources. By contrast, the polar bright auroral band of the double oval can sometimes consist of a series of parallel arcs, not of a single arc, with their multiple structure similar to multiple arcs of the origin in the inner part of CPS as was demonstrated by Echim *et al.* (1997). Thus, there can exist sometimes a morphological similarity of the polewardmost auroral band and multiple auroral features throughout the oval of discrete forms, which could suggest their common physical nature within the CPS, at least for such particular cases.

There are also some minor remarks concerning the Y97 paper. Their main result apparently is (Page 945): '...all auroral arcs found just poleward of isotrophic boundary of >30 keV electrons'. We must note that this result is not new. Evidently, the boundary of stable trapping for the outer belt electrons of >30 keV during steady conditions is one and the same with the IB for electrons of these same energies in the near-midnight sector, at least, the most equatorial IB (see, for example, Burrows and McDiarmid, 1972; GF91). The near collocation of this boundary with the equatorial boundary of the auroral oval of discrete auroral forms was first shown statistically by Feldstein and Starkov (1970), Ackerson and Frank (1972); Feldstein (1974), Vorobiev *et al.* (1976), Lui *et al.* (1977), Lui and Burrows (1978), and then from case studies including satellite measurements of particle spectra by Valchuk *et al.* (1979). This collocation was again demonstrated and used by FG85, FG93, and in other papers on the subject, for example, in GF91, GF96. Indeed, it was the key argument for the mapping scheme where the diffuse auroral belt and respective diffuse precipitation equatorward from the oval are projected to the external part of the outer radiation belt; it is obvious that the region within the trapping zone cannot be mapped to the CPS. The association of the most equatorial auroral arc of the oval at nightside with the inner boundary of the tail current sheet and non-adiabatic ion scattering was also discussed long ago, e.g., in a model by Galperin *et al.* (1992). Thus this experimental result obtained in Y97, as concerns the diffuse auroral belt and equatorial part of the auroral oval, from our point of view, while not new, can be considered as an additional confirmation of the mapping scheme advocated by us for a long time. This seems to be accepted also in Y97.

The last remark concerns the magnetospheric terminology often used which can be misleading especially to students entering the field who are not always aware of past discussions and further clarifications, and thus can take the terminology used in recent papers as a guidance. We believe that there are now obsolete terms the usage of which must be abandoned, and a new terminology elaborated. One such term is 'low-altitude CPS' for the region which concides with the diffuse precipitation within the outer radiation belt, i.e. within the boundary of stable trapping, that has nothing to do with the real CPS in the tail. Another such term is 'low-altitude BPS' which sometimes is still used for the structured precipitation above the auroral oval, the main part of which at nightside is projected to the tail CPS. Some proposals for terminology was described in GF96 and by Newell *et al.* (1996), and we shall be grateful for critical remarks and/or other such proposals for a discussion at forthcoming scientific meetings.

In summary we conclude that:

1. The results of case studies of the relative locations of equatorial auroral arc and isotropy boundary (IB) for energetic electrons in Y97 are in full agreement with the mapping scheme of FG85, GF91 (as confirmed in Y97). Thus we cannot find any "contrast" between the experimental data presented in Y97 with our views.
2. The middle part of Fig. 4 in Y97 entitled 'After Feldstein and Galperin, 1985' significantly distorts our concepts described in that and other our papers on the subject because according to our real scheme:
   a. The region of bright discrete auroral forms, the auroral oval, from its equatorial to its polar arcs, or bands, is mapped to the tail current sheet;
   b. Our scheme, in contrast to the statement by Y97, reflects the important differences in the magnetospheric tail structure for different activity levels. In our scheme, with a change of the activity level, the boundary between diffuse and discrete aurora shifts in latitude while remains close to the stable trapping boundary for the outer belt electrons (>30 keV), or the IB for these electrons;
   c. According to the Fig. 1a, during magnetically quiet intervals, a *bright steady auroral arc* or *band* is mapped on the near-Earth's part of the plasma sheet. Poleward from it, a soft precipitation appears (or, a *soft zone* according to Makita *et al*., 1985). It leads to weak, and variable, auroral features, mostly in the red line emission, within the polar diffuse auroral zone (PDAZ); they map to the distant plasma sheet, possibly, as far as the DNL.
   d. During substorm expansion, the auroral oval is mapped in the plasma sheet between its inner edge and the NNL. During the expansion phase maximum the PDAZ can shrink, so that auroral oval polar border can appear at the DNL.
3. The scheme proposed in Y97 (their Fig. 4) neglects some important observational facts:
   a. The existence of the PDAZ as a distinct structure of auroral precipitation located *poleward* from the bright auroral band or, inverted-V;
   b. Consistent results from many satellites which show that the VDIS-2 ion precipitation structures nearly always are located within the PDAZ, i.e. *outside* the polar bright auroral band of the oval.

In our opinion these misconceptions in Y97, as well as some others, are partly due to non-critical utilization of obsolete terminology still persistent in the literature.

Abbendum. We are somewhat disappointed by the Reply by Yahnin *et al*. (1998) (Y98). The crucial point of our scheme concerning the PDAZ and its mapping, remains unanswered by Y98. Without this principal part of our concepts, as well as with other points indicated herein, it is hard to say that they are "reproduced correctly" as claimed in Y98. As to our identification of the boundary of stable trapping for >30 keV outer belt electrons with the IB for the electrons of these same energies, not only for us but also for many researchers in the field with whom we have consulted, they appear one and the same. However the particle instruments on which Y97 base their study were directed vertically upward, not along the magnetic field line, at 850 km. This makes them look at a side of the loss cone, and sometimes partly outside it for electrons >30 keV above the auroral oval where the inclination of the magnetic field can be $\sim$75–80°. Thus, as stated in Y97 (page 945), these detectors "register the particles both inside and outside the loss cone". This can exaggerate the tendency to isotrophy for electrons >30 keV which, due to enhanced pitch angle scattering and field-aligned potential drops at middle and low auroral altitudes, sometimes can have a rather narrow loss cone at 850 km. The loss cone for energetic protons is wider and not so affected by the inclination.

If the authors of Y97, Y98 are able to show, for electrons > 30 keV, a systematic difference between the IB and the stable trapping boundary in the near-midnight sector, this will be a new and significant result. However for that an apparatus will be needed with a better pitch angle coverage and angular resolution than that used in Y97.

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