Auroral Oval[1]

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Since the concept of the auroral oval was put forward by Feldstein and Khorosheva [cf. *Feldstein et al.*, 1969; *Akasofu*, 1968; *Khorosheva*, 1967] there have been a large number of observations that confirm the presence of the proposed oval configuration of the distribution of auroral arcs and bands. Some of these recent studies are listed below.

1. Occurrence frequency of auroras at six stations over Greenland and Spitzbergen [*Lassen*, 1967, 1970].
2. Occurrence frequency of auroras in the Alaska sector [*Stringer and Belon*, 1967].
3. Occurrence frequency of auroras at Pyramida, Chelyuskin, Murmansk, Verkhoyansk, and others [*Starkov and Feldstein*, 1967, 1968; *Feldstein and Starkov*, 1967].
4. Occurrence frequency of auroras over Antarctica [*Jacka and Bond*, 1968; *Bond and Thomas*, 1971].
5. Airborne observations in the northern polar region [*Buchau et al.*, 1970, 1972].
6. Auroral scanner observations (Isis 2), [*Lui et al.*, 1972].
7. 'Scanning' of the oval by the Alaska meridian chain of stations [*Snyder and Akasofu*, 1972].

There have also been a large number of other types of observations that suggest that the auroral oval provides a 'natural' coordinate in which various polar upper-atmospheric phenomena may be ordered (to enhance understanding).

1. The projection of the outer boundary of the trapping region coincides with the oval [*Akasofu*, 1968; *Feldstein and Starkov*, 1970].
2. The projection of the inner boundary of the plasma sheet coincides with the equatorward boundary of the oval [*Vasyliunas*, 1970; *Feldstein*, 1972].
3. The orientation of extended forms of auroras is parallel to the oval [*Gustafsson*, 1967; *Feldstein and Starkov*, 1967; *Gustafsson et al.*, 1969].
4. Field-aligned currents are present over the auroral oval [*Zmuda et al.*, 1967, 1970].
5. The distinct equatorward boundary of the region of electric field fluctuations coincides with the oval [*Heppner*, 1969; *Maynard and Heppner*, 1970].
6. The electric field changes the polarity in the vicinity of the auroral oval [L. A. Frank, unpublished manuscript, 1972; *Frank and Ackerson*, 1972; *Cauffman and Gurnett*, 1972].
7. The projection of the cusp coincides with the midday part of the oval [*Heikkila and Winningham*, 1971; *Frank*, 1971; *Heikkila et al.*, 1972].
8. Precipitation of soft electrons occurs along the oval [*Hoffman and Berko*, 1971; R. A. Hoffman, unpublished manuscript, 1971; *Frank and Ackerson*, 1971; J. D. Winningham and W. J. Heikkila, unpublished manuscript, 1972].

Recently, *Mishin et al.* [1970*a*, *b*] suggested that the auroral distribution can be better represented by two quasi-circular zones, the 'inner' one being along the dipole latitude circle of 78° and the 'outer' one along the dipole latitude circle of 67°. On the basis of reexamination of their results it is found that the presence of their inner zone is based on observations from a single station, Arctica 2. Their results imply that the inner zone was located precisely at the zenith of Arctica 2. Obviously, this must be due to the fact that the well-known aspect sensitivity of auroras (pointed out by *Elvey et al.* [1953]) has not been properly removed. Further, they supported their suggestion by examining all-sky records from a number of stations

[1] A review paper presented at the symposium on the auroral oval and magnetospheric cusps, April 17–21, 1972. Complete publication in Russian will appear in *Aurora and Airglow*, Moscow, 1973.

along the 200° dipole meridian on February 11, 1958, during the great magnetic storm. The records from the corresponding all-sky records from Arctica 2 were reexamined. It was found that the lower boundary of auroras during midnight hours on that day was not clearly seen. Thus it is not proper to claim that such auroras were distributed along the inner zone, since the distance (from Arctica 2 to the auroras) cannot be determined. *Mishin et al.* [1971] incorrectly identified the twilight and moonlight as the outer zone in their reexamination of the airborne study by *Buchau et al.* [1970]. Other criticisms of their proposed two circular distribution have been published elsewhere [*Starkov et al.*, 1973].

It should be pointed out that the concept of the auroral oval is based on studies of the occurrence of auroral arcs and bands photographed by all-sky cameras. The concept has never implied that characteristics of the precipitation of auroral particles are uniform all along the oval [*Feldstein*, 1969].

Recent progress in the observation of precipitating particles and the resulting luminosities has yielded some additional evidence that characteristics of the oval in the dayside half and nightside half are considerably different [cf. *Heikkila et al.*, 1972; *Eather and Mende*, 1972]. Thus it may be proposed that the oval consists of two parts, the dayside half and the nightside half, although together they form the single oval band. On the basis of recent literature cited earlier, this view is better than the concept of two circular zones put forward by *Mishin et al.* [1970*a*, *b*].

In particular, on very quiet days, auroral arcs and bands are more frequently seen in the dayside half than in the nightside half [*Lassen*, 1967, 1970]. On moderately disturbed days the entire oval can be identified by the presence of auroral arcs and bands. The two regions are connected by a broad band of subvisual glow, even when the occurrence of visible auroras has a discontinuity at the boundary of the regions [*Buchau et al.*, 1972]. It should be noted that there is also another precipitation zone along the auroral zone in the morning sector, which is produced by energetic electrons, particularly during magnetospheric substorms [cf. *Hartz and Brice*, 1967; *Starkov and Feldstein*, 1971].

Figure 1 gives a schematic noon-midnight cross section of the magnetosphere, which indicates the oval location as inferred from aurora and plasma observations in the magnetosphere.

In Figure 2 the position of the auroral oval is related to the intersection lines between the polar ionosphere and the boundary surfaces of different plasma regions in the magnetosphere. The auroral oval is divided into two parts, the dayside and the nightside. Different characteristics of luminescence there are caused by particle precipitation from different plasma regions, such as the magnetosheath on the dayside and the low-latitude plasma sheet on the nightside.

The equatorial oval boundary is indicated by

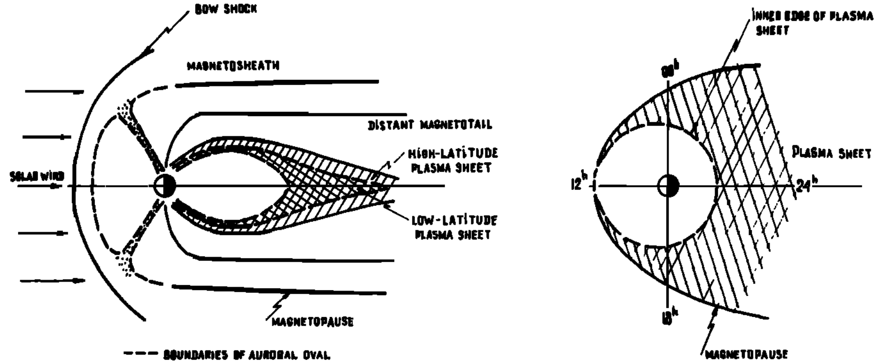

Fig. 1. Schematic cross sections of the magnetosphere and oval position at creation phase. (Left) Cross section in the noon-midnight meridian plane. Shaded region shows the plasma sheet in the tail and the plasma fluxes flowing through the magnetospheric cusps to the upper atmosphere from the tail on the nightside and from the magnetosheath on the dayside. (Right) Schematic section of the magnetosphere in the equatorial plane at the end of the substorm creation phase. Shaded region shows the plasma sheet in the tail.

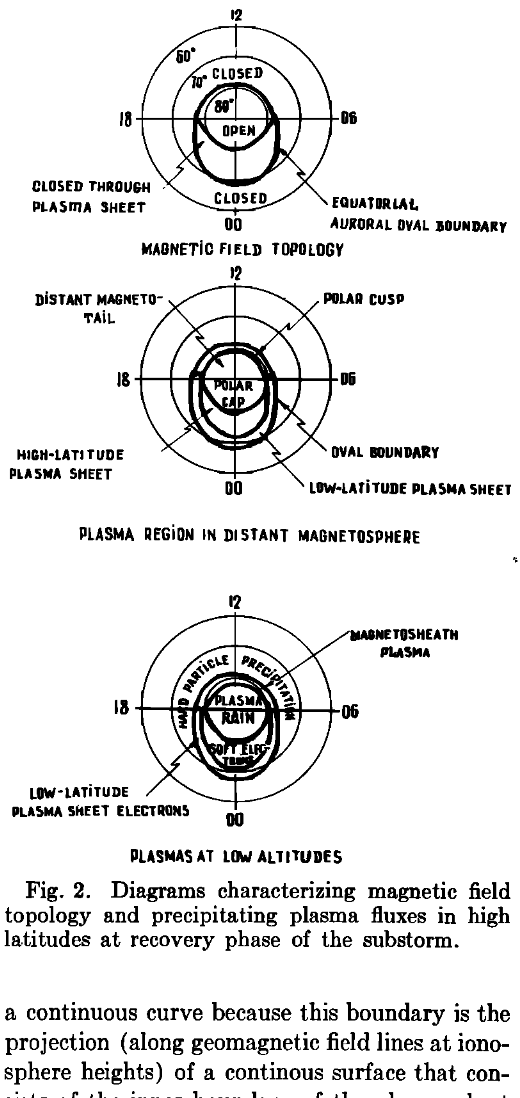

Fig. 2. Diagrams characterizing magnetic field topology and precipitating plasma fluxes in high latitudes at recovery phase of the substorm.

a continuous curve because this boundary is the projection (along geomagnetic field lines at ionosphere heights) of a continous surface that consists of the inner boundary of the plasma sheet in the magnetosphere tail on the nightside of the earth and the magnetopause on the dayside. The two parts of the auroral oval are topologically connected by the large-scale magnetic field structure and plasma population in different regions of the magnetosphere.

References

Akasofu, S.-I., *Polar and Magnetospheric Substorms*, D. Reidel, Dordrecht, Netherlands, 1968.

Bond, F. R., and I. L. Thomas, The southern auroral oval, *Aust. J. Phys., 24,* 97–102, 1971.

Buchau, J., J. A. Whalen, and S.-I. Akasofu, On the continuity of the auroral oval, *J. Geophys. Res., 75,* 7147–7160, 1970.

Buchau, J., G. J. Gassmann, C. P. Pike, R. A. Wagner, and J. A. Whalen, Precipitation patterns in the arctic ionosphere determined from airborne observations, *Ann. Geophys., 28,* 443–454, 1972.

Cauffman, D. R., and D. A. Gurnett, Satellite measurements of high latitude convection electric fields, *Space Sci. Rev., 13,* 369–410, 1972.

Eather, R. H., and S. B. Mende, Systematics in auroral energy spectra, *J. Geophys. Res., 77,* 660–673, 1972.

Elvey, C. T., H. Leinbach, and V. P. Hessler, Preliminary observations of the geographical distribution of auroras in Alaska, *Science, 117,* 466, 1953.

Feldstein, Y. I., Polar auroras, polar substorms, and their relationships with the dynamics of the magnetosphere, *Rev. Geophys. Space Phys., 7,* 179–218, 1969.

Feldstein, Y. I., Auroras and associated phenomena, in *Solar-Terrestrial Physics/1970,* edited by E. R. Dyer, pp. 111, 152–191, D. Reidel, Dordrecht, Netherlands, 1972.

Feldstein, Y. I., and G. V. Starkov, Dynamics of auroral belt and polar geomagnetic disturbances, *Planet. Space Sci., 15,* 209–229, 1967.

Feldstein, Y. I., and G. V. Starkov, The auroral oval and the boundary of closed field lines of geomagnetic field, *Planet. Space Sci., 18,* 501–508, 1970.

Feldstein, Y. I., S. I. Isaev, and A. L. Lebedinsky, Phenomenology and morphology of aurorae, *Ann. Int. Quiet Sun Year, 4,* 311–348, 1969.

Frank, L. A., Plasma in the earth's polar magnetosphere, *J. Geophys. Res., 76,* 5202–5219, 1971.

Frank, L. A., and K. L. Ackerson, Observations of charged particle precipitation in the auroral zone, *J. Geophys. Res., 76,* 3612–3643, 1971.

Frank, L. A., and K. L. Ackerson, Local-time survey of plasma at low altitudes over the auroral zones, *J. Geophys. Res., 77,* 4116–4127, 1972.

Gustafsson, G., On the orientation of auroral arcs, *Planet. Space Sci., 15,* 277–294, 1967.

Gustafsson, G., Y. I. Feldstein, and N. F. Shevnina, The auroral orientation curves for the IQSY, *Planet. Space Sci., 17,* 1657–1667, 1969.

Hartz, T. R., and N. M. Brice, The general pattern of auroral particle precipitation, *Planet. Space Sci., 15,* 301–329, 1967.

Heikkila, W. J., and J. D. Winningham, Penetration of magnetosheath plasma to low altitudes through the dayside magnetospheric cusps, *J. Geophys. Res., 76,* 883–891, 1971.

Heikkila, W. J., J. D. Winningham, R. H. Eather, and S.-I. Akasofu, Auroral emissions and particle precipitation in the noon sector, *J. Geophys. Res., 77,* 4100–4115, 1972.

Heppner, J. P., Magnetospheric convection patterns inferred from high latitude activity, in *Atmospheric Emissions,* edited by B. M. McCormac and A. Omholt, pp. 251–266, Van Nostrand Reinhold, New York, 1969.

Hoffman, R. A., and F. W. Berko, Primary electron influx to the dayside auroral oval, *J. Geophys. Res.*, *76*, 2967–2976, 1971.

Jacka, F., and F. R. Bond, Optical auroral morphology, *Ann. Geophys.*, *24*, 547–554, 1968.

Khorosheva, O. V., Spatial-temporal distribution of aurorae, in *Aurorae* (in Russian), no. 16, pp. 1–84, Academy of Sciences, Moscow, 1967.

Lassen, K., Polar cap aurora, in *Aurora and Airglow*, edited by B. M. McCormac, pp. 453–464, Reinhold, New York, 1967.

Lassen, K., The position of the auroral oval over Greenland and Spitzbergen, *Phys. Norv.*, *4*, 171–175, 1970.

Lui, A. T. Y., C. Anger, and S.-I. Akasofu, Observations of the auroral oval and a westward traveling surge from Isis 2 satellite and Alaska meridian all sky cameras, submitted to *J. Geophys. Res.*, 1972.

Maynard, N. S., and J. P. Heppner, Variations in the electric fields from polar orbiting satellites, in *Particles and Fields in the Magnetosphere*, edited by B. M. McCormac, pp. 247–253, D. Reidel, Dordrecht, Netherlands, 1970.

Mishin, V. M., T. I. Saifudinova, and I. A. Zhulin, Two zones of precipitating energetic particles, *J. Geophys. Res.*, *75*, 797–806, 1970*a*.

Mishin, V. M., V. P. Samsonov, T. I. Saifudinova, and V. A. Kurilov, Main zones of corpuscular invasions into ionosphere, *Invest. Geomagn. Aeron. Solar Phys.* (in Russian), no. 11, 3–23, 1970*b*.

Mishin, V. M., V. P. Samsonov, G. V. Popov, and T. I. Saifudinova, New data on zones of corpuscular invasions into the polar ionosphere, *Invest. Geomagn. Aeron. Solar Phys.* (in Russian), no. 19, 38–44, 1971.

Snyder, A. L., and S.-I. Akasofu, Observations of the auroral oval by the Alaskan meridian chain of stations, *J. Geophys. Res.*, *77*, 3419–3430, 1972.

Starkov, G. V., and Y. I. Feldstein, Variation of auroral oval boundaries, *Geomagn. Aeron.*, *7*, 62–71, 1967.

Starkov, G. V., and Y. I. Feldstein, Auroral oval during magnetic disturbances, in *Aurorae*, no. 17, pp. 22–33, Academy of Sciences, Moscow, 1968.

Starkov, G. V., and Y. I. Feldstein, Auroral substorm, *Geomagn. Aeron.*, *11*, 560–562, 1971.

Starkov, G. V., Y. I. Feldstein, and O. V. Khorosheva, Eccentric oval or two quasi-circular zones, *Invest. Geomagn. Aeron. Solar Phys.*, in press, 1973.

Stringer, W. J., and A. E. Belon, The morphology of the IQSY auroral oval, *J. Geophys. Res.*, *72*, 4415–4421, 1967.

Vasyliunas, V. M., Low energy particle fluxes in the geomagnetic tail, in *The Polar Ionosphere and Magnetospheric Processes*, edited by G. Skovli, Gordon and Breach, New York, 1970.

Zmuda, A. J., F. T. Heuring, and J. H. Martin, Dayside magnetic disturbances at 1100 kilometers in the auroral oval, *J. Geophys. Res.*, *72*, 1115–1117, 1967.

Zmuda, A. J., J. C. Armstrong, and F. T. Heuring, Characteristics of transverse magnetic disturbances observed at 1100 kilometers in the auroral oval, *J. Geophys. Res.*, *75*, 4757–4762, 1970.

(Received April 12, 1972;
accepted October 27, 1972.)
Communicated by S.-I. Akasofu.